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EVALUATING THE BOUNDARY CONDITION OF TURBOJET ENGINE IN MATLAB

Dinesh Kumar[1], Dr. RK Gupta[2]
[1]M.Tech, [2]HOD, (Mechanical Engineering), GITM, Bilaspur, MDU Rohtak

ABSTRACT: A proposed MATLAB program on jet engine provides the output for the basic information like temperature variation, Pressure variation &Mass Flow Variation. Simulation result of Jet engine is most necessary part of this experiment for CFD analysis. Variation of input parameter will provide a systemic analysis of jet engine from ambient to exaust.We have separate analysis over the each part of jet engine. In future this technique will be added with more parameter for complete analysis of jet engine for its CFD analysis. This will enhance the capability of manufacturing side of engine which has to make better engine efficiency and aerodynamic shape. A structured series of CFD aided investigation and performance analysis is performed. These processes are based on a series of analyses which are evaluated with the influence of a number of cell parameters in the terms of temperature, Pressure &Mass Flow Variation of turbojet engine. Five cell components are used to investigated the individual analyses namely, the inlet and exhaust stack baffle arrangements, the Ambient to Inlet , Inlet to compressor and compressor to combustor, combustor to turbine, and last turbine to exhaust,. Throughout the investigations the value of CFD as a design tool was constantly assessed. Overall, the findings suggest that parametric optimization of the baffle arrangements would provide the deep analysis of pressure, temperature and mass flow variation. Computational Fluid Dynamics is used to aid model development and the model is calibrated to validate against ground test data. The proposed CFD technique is used to quantify the performance of several educator configurations throughout the range of expected operating conditions and to quantify the amount of variation and efficiency beside few of them is constant parameters.

Key Word: CFD, MATLAB, Turbojet, Temperature variation, Pressure &Mass Flow Variation.

I. INTRODUCTION

1.1 Concept of Computational Fluid Dynamics

Computational fluid dynamics is a branch of fluid dynamics. It provides a qualitative prediction of fluid flows by means of mathematical modeling, numerical methods, software tools . Verification amounts to looking for errors in the implementation of the models examine the computer programming by visually checking the source code, documenting it and testing the underlying subprograms individually. Computational techniques replace the governing partial differential equations with systems of algebraic equations that are much easier to solve using computers.

1.2 Brief Introduction of JET

A Jet Engine is a response Engine releasing a quick moving Jet that creates push by Jet impetus. This wide definition incorporates turbojets, turbofans, rocket Engines, ramjets, and heartbeat Jets. As a rule, Jet Engines are burning Engines. In like manner speech, the term Jet Engine freely alludes to an inner ignition air breathing Jet Engine. These normally highlight a pivoting air compressor fueled by a turbine, with the extra power giving push by means of an impelling spout this procedure is known as the Brayton thermodynamic cycle. Jet flying machine utilize such Engines for long-remove travel. Early stream air ship utilized turbojet Engines which were moderately wasteful for subsonic flight. Cutting edge subsonic Jet flying machine typically utilize more mind boggling high-sidestep turbofan Engines. These Engines offer rapid and more prominent fuel proficiency than cylinder and propeller aero engines over long separations.

1.3 Uses

Jet engines power jet aircraft, cruise missiles and unmanned aerial vehicles. In the form of rocket engines they power fireworks, model rocketry, space flight, and military missiles. Jet engines have propelled high speed cars, particularly drag racers, with the all-time record held by a rocket car. A turbofan powered car, Thrust SSC, currently holds the land speed record. Jet engine designs are frequently modified for non-aircraft applications, as industrial gas turbines or marine power plants. These are used in electrical power generation, for powering water, natural gas, or oil pumps, and providing propulsion for ships and locomotives. Industrial gas turbines can create up to 50,000 shaft horsepower. Many of these engines are derived from older military turbojets such as the Pratt & Whitney J57 and J75 models. There is also a derivative of the P&W JT8D low-bypass turbofan that creates up to 35,000 HP.Jet engines are also sometimes developed into, or share certain components such as engine cores, with turbo shaft and turbopropengines, which are forms of gas turbine engines that are typically used to power helicopters and some propeller-driven aircraft.

II. LITERATURE SURVEY

Dominik Klein & Chamil Abeykoon proposed for Gas Turbine that are one of the most important internal combustion engines in the modern world's transportation. Any possible improvements of the performance of the gas turbine engines would help to minimize the world's annual fossil fuel consumption and hence the emissions of the adverse greenhouse gases. Therefore, modelling and simulation of gas turbines have been a major focus of many fields in aviation to improve their performance. In this work, it is aimed to model a turbojet gas turbine engine theoretically and computationally.[1] YANG Jiali, ZHU Jihong suggested in the year of 2015, for Thrust vector that can effectively improve the fighter's maneuverability and flight safety, increasing the survival rates in the air combat. As the key component of thrust vectors, the turbojet engine's dynamics and characteristics have a great influence on the performance and control of thrust vectors. This paper would model the dynamics of a small scale turbojet engine through experiment and identification.[2] Zdeněk Katolický , Bohuslav Bušov and Milada Bartlová suggested for concurrent small turbojet engines .This Czech design has several important parametrical advantages weight, power, reliability, cost, etc. Innovations were obtained by creative/inventive solutions in which several instruments TRIZ were used objectively. In this article, the turbojet engine is presented as a case study: As an example for teaching the TRIZ methodology to students and engineers and as a solution of turbojet engine for small and unmanned air vehicles.[3] Wu Yong-hai suggested, A four-stroke direct injection diesel engine that is taken as the study object, and a cylinder-jacket-coolant-piston coupling model is built up. With the research method of fluid solid- heat coupling, the computational regions of both fluid and solid are coupled, which are separated in traditional temperature-field computation, and the puzzle of iterating difficultly due to the differences of temperature governing equations and numerical algorithms is solved.[4] Dinesh Kumar T & Dr. R. Ramesh suggested in the year of 2013 for Drag that is an undesirable but inevitable component of force in an Aircraft. In order to improve the performance of the Aircraft, it is desired to have a reduced Drag. In Fighter Aircrafts the accurate prediction of flow at various Altitude and Mach numbers will be helpful predict the performance of the Aircraft. At the intake of the Engine, the mass flow rate is restricted by the throttle control, and only desired mass of air enters the engine as per the requirements.[5]

III. EARLIER WORK

3.1 Dominik Klein & Chamil Abeykoon proposed in his paper about gasturbine and its simulation. Gas turbines are one of the most important internal combustion engines in the modern world's transportation. Any possible improvements of the performance of the gas turbine engines would help to minimize the world's annual fossil fuel consumption and hence the emissions of the adverse greenhouse gases. Therefore, modelling and simulation of gas turbines have been a major focus of many fields in aviation to improve their performance. In this work, it is aimed to model a turbojet gas turbine engine theoretically and computationally. On this basis, the pre-established equations were implemented in MATLAB Simulink to create a model of a turbojet engine. The influence of atmospheric conditions was also taken into account in creating the model. Furthermore, GasTurb was used to study the turbojet engines and provided useful results to explore the engine performance. The theoretical and Simulink models were in a good agreement within reasonable limits which verifies the correctness of the Simulink model established in this paper. Therefore, the proposed model can be used in investigating the performance of various types of turbojet engines without performing time taking theoretical calculations.

3.2 Basic operation of gas turbines

A gas turbine is an internal combustion engine. Today most of the modern passenger, cargo and military aircrafts arepowered by various size/type of gas turbine engines. A turbine basically consists of five components: intake, compressor, combustion chamber, turbine and propelling nozzle. The principle of operation can be described in terms of simple steps. The air flows through the inlet into the compressor with one or more compression stages where the compressor will deliver a high pressure air flow that required in the turbine inlet. Energy is then added by spraying fuel into the air and igniting it in the combustion chamber. The combustion generates a high temperature flow, which consists of a mixture of combustion gas and air. The high temperature and high pressure gas enters the turbine and expands down to the exhaust pressure. One part of the energy is converted into kinetic energy or rotational energy, which produces a shaft work output in the process. Thereby, the compressor is driven. The other part produces the thrust in the propelling nozzle. Thrust is a mechanical force which is generated through the reaction of accelerating a mass of gas. A schematic diagram of the engine arrangement and the typical temperature entropy and pressure-volume diagrams of a gas turbine engine are shown in Figure 1.

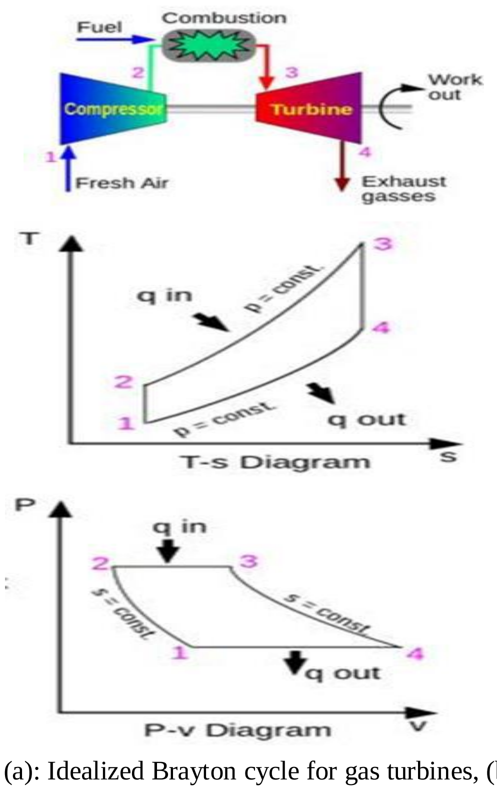

Fig I: (a): Idealized Brayton cycle for gas turbines, (b): T-s Diagram, (c): P-VDiagram

3.3 Earlier work on Turbojet

he first centrifugal-flow turbojet was invented in 1930 by Frank Whittle of the Royal Air Force, and in Germany, Hans vonOha in also patented a similar engine in 1935. Since then turbojet engines have been widely popular and they are still common in medium range cruise missiles, possibly due to their high exhaust speed, small frontal area, and relative simplicity. A turbojet turbine is designed such that it generates the power for driving the compressor and thrust for moving the aircraft. The entire gas flow is conducted through the combustion chamber and the expansion of the exhaust gases in the propelling nozzle to atmospheric pressure to produce a very fast thrust jet. Due to the high exit velocity of the exhaust jet, the turbojet gas turbines are low in efficiency at low speeds. Especially at subsonic speeds (i.e., at low speeds) the specific fuel consumption is high. Because of the fast jet, the turbojet gas turbine produces a high noise level, which limits their usefulness. As per improvements over the time, turbojets have been replaced in slower aircraft by turboprops which use less fuel. At higher speeds, they have been replaced by turbofans as the propeller is no longer efficient. Basically, the turbofan is quieter and uses less fuel than the turbojet.

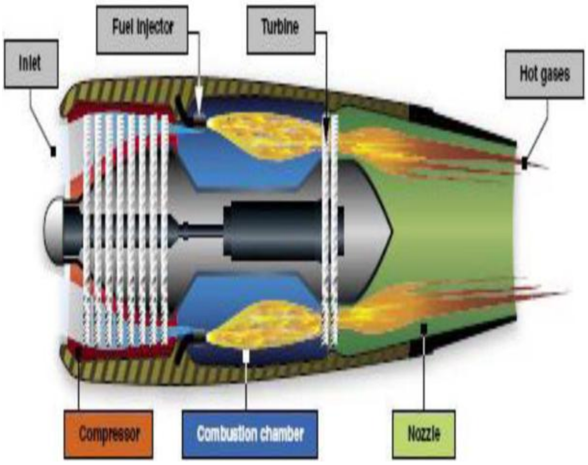

Fig 3.1 Turbojet engine and its different components

Basic Operational Parameters The difference between shaft power cycles and aircraft gas turbine cycles is the useful power output. For turbojets the thrust is generated in the propelling nozzle. With gas turbines, higher speeds and greater heights can be achieved and hence the reciprocating engines were replaced by gas turbines. The intake of this type of gas turbines must be considered as a separate component because of its significant effects on the forward speed. The intake has an effect on the engine efficiency and aircraft safety.

3.4 RESULTS AND DISCUSSION

At different flight conditions both the thrust and specific fuel consumption will vary, due to the change in the air mass flow with varying density and the variation of momentum drag with the forward speed. Furthermore, even if the engine were run at a fixed rotational speed, the turbine inlet temperature will change with intake conditions.

IV. PROPOSED METHODOLOGY

In these methodologies the same essential strategy is taken for simulation as discussed earlier with little change.

4.1 During preprocessing

•The geometry (physical limits) of the issue is characterized.

•The volume possessed by the fluid is partitioned into discrete cells (the lattice). The cross section might be uniform or non-uniform.

•The physical displaying is characterized for instance, the conditions of movement + enthalpy + radiation + species protection

•Boundary conditions are characterized. This includes indicating the fluid conduct and properties at the limits of the issue. For transient issues, the underlying conditions are likewise characterized.

•The reproduction is begun and the conditions are understood iteratively as a consistent state or transient.

•Finally a postprocessor is utilized for the investigation and perception of the subsequent arrangement.

4.2 Discretization techniques

The steadiness of the chose discretisation is by and large settled numerically as opposed to logically as with basic direct issues. Unique consideration should likewise be taken to guarantee that the discretisation handles spasmodic arrangements effortlessly. The Euler conditions and Navier–Stokes conditions, both concede stuns, and contact surfaces.

4.3 .Mathematical modeling for Proposed Work

$$F_N = (\dot{m}_{air} + \dot{m}_f)V_j - \dot{m}_{air}V$$

Where:

$\dot{m}_{air}$	is the rate of flow of air through the engine
$\dot{m}_f$	is the rate of flow of fuel entering the engine
V_j	is the speed of the jet (the exhaust plume) and is assumed to be less than sonic velocity
V	is the true airspeed of the aircraft
$(\dot{m}_{air} + \dot{m}_f)V_j$	represents the nozzle gross thrust
$\dot{m}_{air}V$	represents the ram drag of the intake

If the speed of the jet is equal to sonic velocity the nozzle is said to be choked. If the nozzle is choked the pressure at the nozzle exit Jet is greater than atmospheric pressure, and extra terms must be added to the above equation to account for the pressure thrust.

The rate of flow of fuel entering the engine is very small compared with the rate of flow of air. If the contribution of fuel to the nozzle gross thrust is ignored, the net thrust is:

Comp Ratio	Air Flow Ratio	Compressor Loss	Inlet Ratio	Fuel Flow Ratio	Router Speed
30	19.9	4	1	0.380	16540
30	19.9	4	1	0.380	18000
30	45	4	1	0.380	18000

Output 1: Pressure Variation	Output 2: Temperature Variation	Output 3: Mass Flow Variation
Fig. 5.2	Fig 5.3	Fig 5.4
Fig 5.5	Fig 5.6	Fig 5.7
Fig 5.8	Fig 5.9	Fig 5.10

$$F_N = \dot{m}_{air}(V_j - V)$$

The speed of the jet V_j must exceed the true airspeed of the aircraft V if there is to be a net forward thrust on the airframe. The speed V_j can be calculated thermodynamically based on adiabatic expansion.

4.4 Simulation Code and Parameters

R %287; % [J/Kg.K] Gas Constant
Cp_air %1000; % [J/Kg.K] Specific heat of hot air
Cp_gas %1150; % [J/Kg.K] Spec . heat of flue gasses
Cp_mix %1050; % [J/Kg.K] Spec . heat after mixer of turbofan
Gamma_air %1.4; % [-] Isentropic Coefficient air
Gamma_gas %1.33; % [-] Is. Coeff . of flue gasses
Gamma_mix %1.38; % [-] Is. Coeff . after mixer of turbofan
H_f %4.32E7; % [J/Kg] Fuel Heating value

V. SIMULATION & RESULT

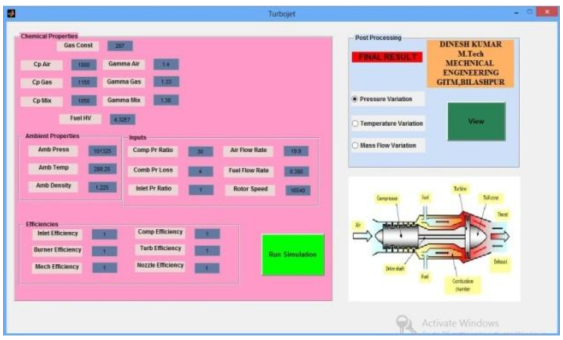

Fig 5.1: Main GUI

We consider efficiencies, chemical properties and ambient properties as a fixed or constant value. Here, the change is only in the inputs values like Compression per ratio, Air flow ratio, etc. for creation of Table 5.1. Further air flow rate increases till the line of mass flow variation remains horizontal. It provides the boundary condition of turbojet.

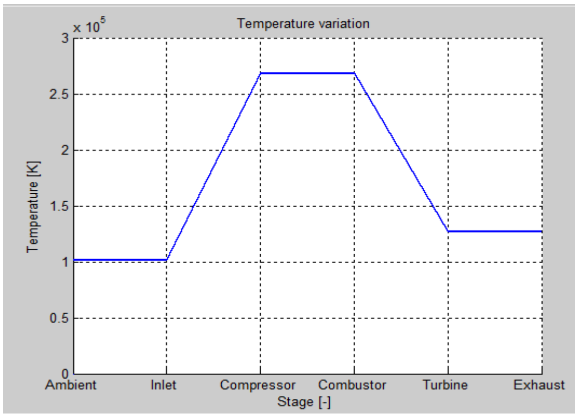

Fig 5.2 : Temperature Variation (Stage vs Temprature)

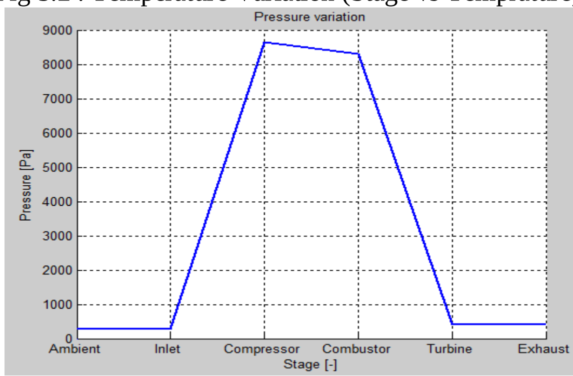

Fig 5.3 PressureVariation (Stage vs Pressure)

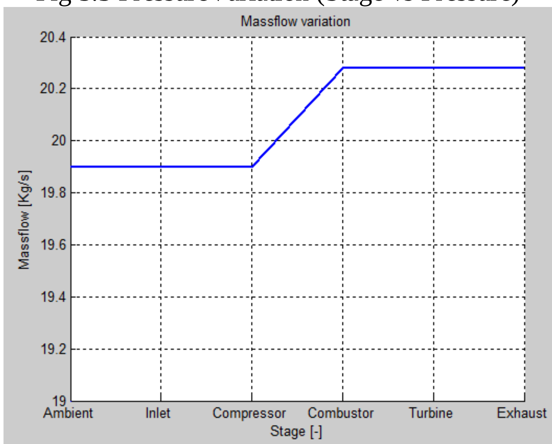

Fig 5.4: Mass flow Variation (Stage vs Massflow)

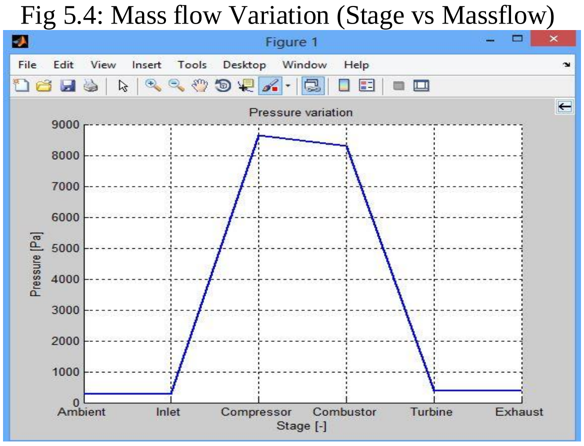

Fig 5.5: Temperature Variation

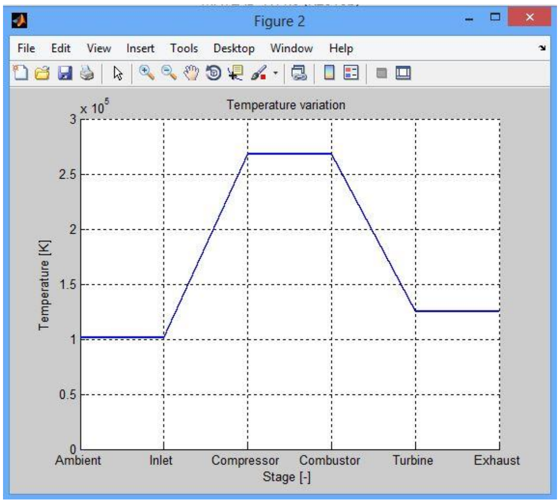

Fig 5.6: Pressure Variation

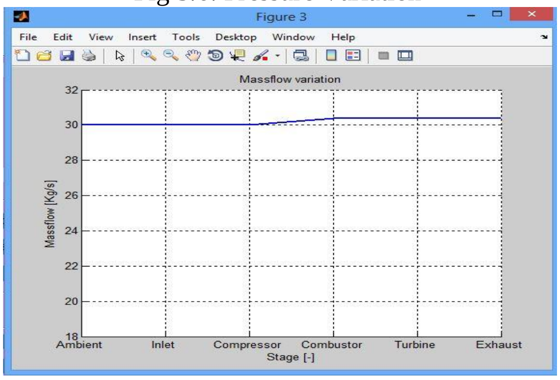

Fig 5.7: Mass Flow Variation

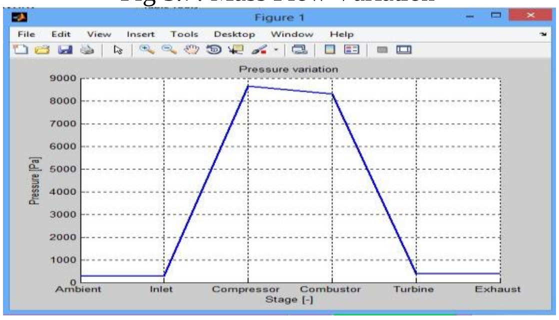

Fig 5.8: Temperature Variation

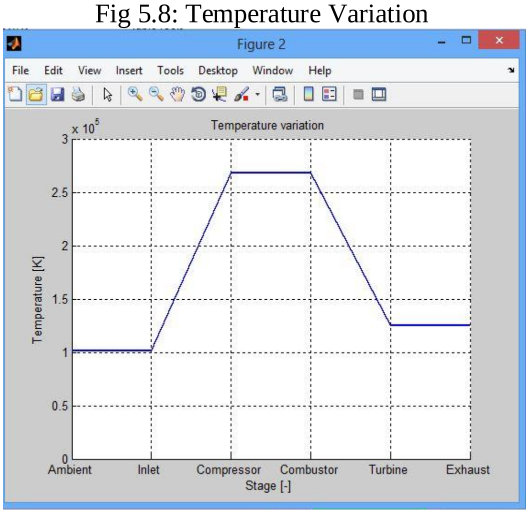

Fig 5.9: Pressure Variation

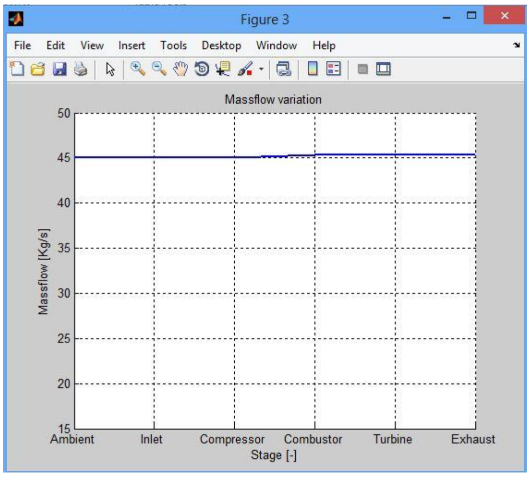

Fig 5.10: Mass Flow Variation

Table 5.1: Variation of input(R is constant, Stage is the collection on input one time in simulation

		Stage 1	Stage2	Stage3
Gas constant	287	R	R	R
Cp Air	1000	R	R	R
Cp Gas	1150	R	R	R
Cp mix	1050	R	R	R
Gamma Air	1.4	R	R	R
Gamma Gas	1.33	R	R	R
Gamma mix	1.38	R	R	R
Amb press	101325	R	R	R
Amb Temp	288	R	R	R
Amb density	1.225	R	R	R
Comp pr ratio	30	R	R	R
Comp pr loss	4	R	R	R
Inlet pr ratio	1	R	R	R
Air flow rate	19.9	R	R	30
Fuel flow rate	0.38	R	R	R
Rotor speed	16540	R	R	18000
Inlet efficiency	1	1	2	1
Burnar Efficiency	1	1	2	1
Mech Efficiency	1	1	2	1
Comp efficiency	1	1	2	1
Turb Efficiency	1	1	2	1
Nozzle Efficiency	1	1	2	1

Table 5.2: Result (PV – Pressure Variation, TV- Temp variation,MVF-Mass Flow Variation)

	PV1	TV1	MFV1	PV2	TV2	MFV2
Ambient-inlet	CON	CON	CON	CON	CON	CON
Inlet to compressor	INC	INC	CON	INC	INC	CON
Compressor to combstor	S-DE	CON	INC	S-DEC	CON	INC
Combstor to turbine	DEC	DEC	CON	S-DEC	DEC	CON
Turbine to exaust	CON	CON	CON	CON	CON	CON

5.1 Experimental condition

In figure 5.10 we find a constant horizontal line throughout the ambient to exhaust. It shows a no variation of mass flow through turbojet engine. It also provides a boundary condition of our input value. After the insertion of each parameter we can find the boundary condition of each simulation output line temperature variation.

VI. CONCLUSION AND FUTURE WORK

The result come out from the MATLAB programe on jet engine provide the output for the basic information like tempreture variation, Pressure variation &Mass Flow Variation. Simulation result of Jet engine are most necessary part of this experiment for CFD analysis.Variation of input parameter will provide a systemic analysis of jet engine from ambient to exaust.We have separate analysis over the each part of jet engine. In future this technique will be added with more parameter for complete analysis of jet engine for its CFD analysis. This will enhance the capability of manufacturing side of engine which has to make better engine efficiency and aerodynamic shape. Further variation of each parameter will provide a boundary condition of proposed model for turbojet engine.

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