CFD Simulation of Micro Combustor

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Abstract— **In this , I present the design of the tubular micro combustion chamber followed by the 3-Dimensional simulation in combustor to investigate the velocity profile, species concentration and temperature distribution with in the liner, fuel considered as HYDROGEN. The computational approach attempts to strike a reasonable balance to handle the competing aspects of complicated physical and chemical interactions of the flow.The modelling employs Non-Orthogonal curvilinear coordinates, Second order accurate discritization, Tetra grid iterative solution procedure, the SST-□ turbulence model. Accordingly, in present study an attempt as been made through CFD approach using ANSYS CFX-14.0 to analyse the flow pattern in the combustion linear and through air admission holes and from these temperature distribution in the liner and at walls as well as the temperature quality at the exit of combustion chamber is obtained.**

Keywords— **Hydrogen, discretization, turbulence.**

1. Introduction

GAS TURBINE ENGINE

A gas turbine, likewise called a combustion chamber, is a kind of interior burning engine.

Energy can be separated as shaft force, packed air or push or any mix of these and utilized of force flying machine, trains, boats, generators, or even tanks.

Fig A Typical Axial-Flow Gas Turbine Turbojet

1.2 THEORY OF OPERATION OF GAS TURBINE ENGINE

Gasses experiencing an impeccable gas turbine experience three thermodynamic processes. These are Isentropic Compression, Isobaric [constant pressure] combustion and isentropic expansion. Together these make up the Brayton Cycle.

In a viable gas turbine, gasses are initially quickened in either an outward or hub compressor. These gasses are then moderated utilizing a different spout known as a diffuser; these procedures build the weight and temperature of the stream. In a perfect framework this is isentropic. In any case, for all intents and purposes imperativeness is lost to warm, in light of grinding and turbulence. Gasses then go from the diffuser to a blazing chamber, or practically identical device, where warmth is incorporated. In a flawless structure this happens at relentless weight [isobaric heat addition]. As there is no change in weight the specific volume of the gasses increases. In helpful circumstances this technique is ordinarily joined by a slight setback in weight, in light of contact. Finally, this greater volume of gasses is expanded and revived by spout guide vanes before imperativeness is removed by a turbine. In an impeccable structure these are gasses amplified isentropically and leave the turbine at their novel weight. For all intents and purposes this technique is not isentropic as imperativeness is by the day's end lost to contact and turbulence.

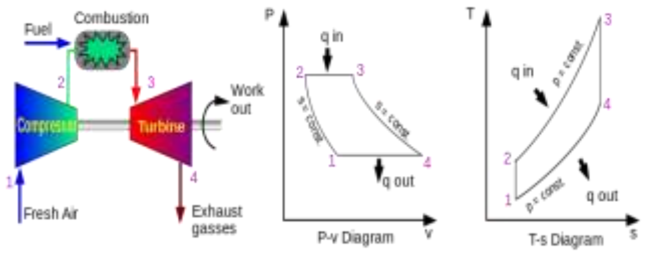


Fig Typical Working Cycle Of Gas Turbine Engine With Its P-V Diagram & T-S Diagram

TYPES OF GAS TURBINE ENGINES

- Jet engines
- Turboprop engines
- Aero derivative gas turbines
- Amateur gas turbines
- Auxiliary power units
- Industrial gas turbines for power generation
- Compressed air energy storage
- Turbo shaft engines
- Radial gas turbines
- Scale jet engines
- Micro turbines

Fig Diagram Of A High-Pressure Turbine Blade

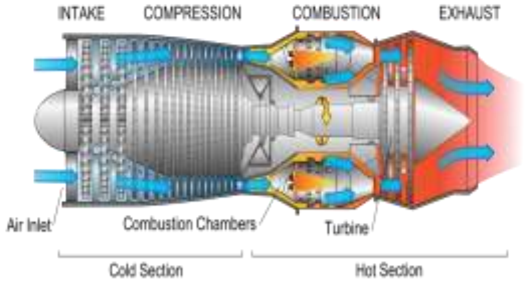


Fig Diagram of a gas turbine jet engine

1.4 SCOPE OF PRESENT WORK

In this project, I display the outline of the tubular miniaturized scale ignition chamber took after by the three dimensional in combustor to examine the speed profiles, species fixation and temperature dispersion inside the liner, and fuel considered as HYDROGEN. The extent of present work is to break down the stream design in the ignition straight and through air affirmation openings and from these the temperature appropriation in the direct and at dividers and in addition the temperature quality at the way out of burning chamber is gotten.

OUTLINE OF THE THESIS

The theory contains nine parts. The different sections of the proposition are sorted out as per the accompanying succession.

Section 1 introduction to gas turbine. Part 2 surveys the past work concerning trial and hypothetical examinations identified with an investigation of Micro-combustor inspected from some papers. Part 3 talk about the material science of the diverse sorts of Micro-combustor and significance of Micro-combustor. Part 4 gives data about burning procedure, Chapter5 and 6 give the points of interest of numerical strategy, computational subtle elements for present study, which incorporate the portrayal of overseeing conditions, geometrical demonstrating, framework era, set up of the numerical model, and so on.

MICRO COMBUSTOR

INTRODUCTION

A combustor must contain and keep up stable blazing regardless of high wind stream rates. To do all things considered combustors are meticulously expected to first mix and touch off the air and fuel, and after that mix in more air to complete the ignition strategy. Early gas turbines engines used a single chamber known as a can sort combustor. Today three rule plans exist; can, annular and cannular. Max motor drive is as often as possible saw as another kind of combustor.

Combustors assume a pivotal part in deciding huge numbers of motors working attributes, for example, fuel effectiveness, levels of discharges and transient reaction.

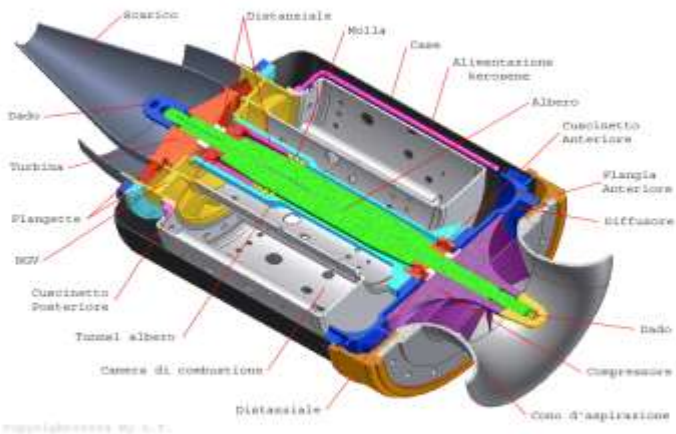
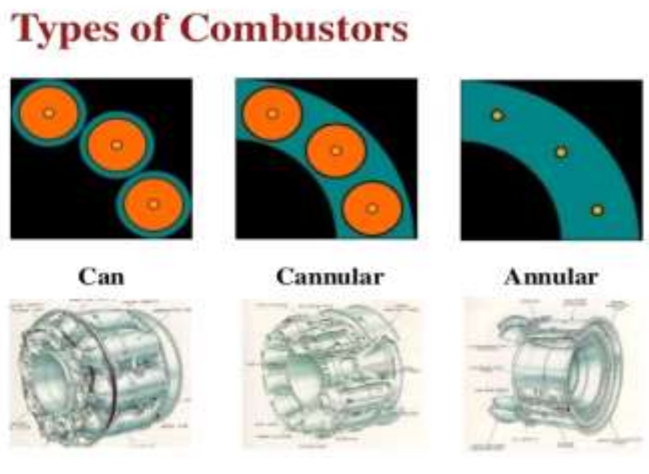


Fig Typical Micro Combustor

TYPES OF COMBUSTOR

- **Can combustor**
- **Cannular combustor**
- **Annular combustor**



Can Combustor annular Combustor Annular

COMBUSTION

Ignition is an unpredictable succession of exothermic synthetic responses between a fuel and an oxidant joined by the generation of warmth or both warmth and light as either a shine or flares. Ignition is the concoction response which happens when substances smolder. Burning is a case of oxidation. Oxides are made.

Ignition is a convertion of a substance called a fuel into synthetic mixes known as results of burning by mix with an oxidizer. The burning procedure is an exothermic compound response, i.e., a response that discharges vitality as it happens. Subsequently ignition might be spoken to typically by

Fuel+oxidizer= results of combustion+energy

In acomplete burning response, a compound responds with an oxidizing component and the item are mixes of every component in the fuel with the oxidizing component.

For instance

$CH_2 + 2O_2 = CO_2 + 2H_2O$

$CH_2S + 6F_2 = CF_4 + 2HF + SF_6$

a less complex illustration can be found in the ignition of hydrogen and oxygen, which is a normally utilized as a part of the burning of hydrogen and oxygen, which is a generally utilized response as a part of rocket motors;

$2H_2 + O_2 = 2H_2O$ g + heat

Hydrogen gas is exceedingly combustible and will smolder in air at a vaery extensive variety of fixation between 4 percent and 75 percent by volume. The enthalpy of ignition for hydrogen is - 286 kj/mol.

- These responses of condition [4.4, 4.5 and 4.6] will be characterized as far as stoichiometric coefficient, arrangement enthalpies , parameters that controls response rate .the response rate will be resolved expecting that turbulent blending is the rate constraining procedure, with the turbulent –chemistry association displayed utilizing the swirl dispersal model.
- The substance species in the framework and their physical and thermodynamic properties are characterized by our determination of the blend material, Hydrogen responds with oxygen to shape s2o has appeared in the above condition 4.4
- Octane responds with oxygen and structures co2 and h2o as appeared in condition 4.5
- Octane turned out to be surely understood in American mainstream culture in the brain and late – sixities, when gas organizations gloated of 'high octane' levels in their fuel on TV advertisements. This business are alluding to the octane rating , which is a measure for the counter thumping properties of gasoline.the octane rating is not identified with the measure of octane contained in the gas

$C_8H_{18} + 12.5O_2 = 8CO_2 + 9H_2O$

Kerosene responds with oxygen and structures co2 and H_2O as appeared in condition 4.6

$C_{15}H_{32} + 23O_2 = 15CO_2 + 16H_2O$Lamp fuel is amixture of hydrocarbons of 12 to 15 or more carbons. Lamp fuel is a slim, clear fluid shaped from hydrocarbons, with thickness of 0.78-0.81g/cm3. Light oil is gotten from the fragmentary refining of petroleum some place around 1500c and 2750c, achieving a mix of carbon chains that frequently contain some place around 6 and 16 carbon particles for each modlecue. The blast motivation behind light oil is some place around 37 and 650c [100-1500f] and its autoignition temperature is 2200c [4280f]. in the immeasurable bigger piece of this present reality usage of ignition, the oxygen [o2] oxidant is procured from the encompassing air and the resultant vent gas from the smoldering will contain nitrogen;

$CH_4 + 2O_2 + 7.52N_2 = CO_2 + 2H_2O + 7.52N_2 + HEAT$

TYPES OF COMBUSTION

- **RAPID**

Fast ignition is a type of burning in which a lot of warmth and light vitality are discharged, which frequently brings about a flame. This is utilized as a part of a type of apparatus, for example, inner ignition motors and in thermobaric weapons. Now and then, a vast volume of gas is freed in burning other than the generation of warmth and light. The sudden development of substantial quanties of gas makes exorbitant weight that delivers an uproarious commotion. Such ignition is known as a blast.

- **SLOW**

Moderate ignition is a type of burning which happens at low temperature. Cell breath is a case of moderate combustion.

FUELS

- **Gaseous Fuel**
  - Natural gas
  - Refinery gas
- **Liquid Fuels**
  - Kerosene
  - Gasoline, diesel
  - Alcohol[ethanol]
  - Oil
- **Solid Fuels**
  - Coal [anthracite , bituminous, subbituminous, lignite]
  - Wood

TEMPERATURE

Expecting impeccable ignition conditions, for instance, complete smoldering under adiabatic conditions [i.e., no glow incident or gain], the adiabatic ignition temperature can be determined . the condition that yields this temperature relies on upon the essential law of thermodynamics and watches that the glow of ignition is used thoroughly to warm the fuel , the smoldering air or oxygen , and the ignition thing gasses [consistently insinuated as the funnel gas].

INSTABILITIES

Burning hazards are regularly fierce weight `oscillations in an ignition chamber. These weight motions can be as high as 180dB, and long haul introduction to these cyclic weight and warm and warm loads diminishes the life of motor segments. in rocket ,, for example, the F1 utilized as a part of the Saturn V program , hazards prompted gigantic harm of the burning load and encompassing segments . this issue was tackled by upgrading the fuel injector . in fluid plane motors the bead size and appropriation can be utilized to lessen the insecurities . burning insecurities are a noteworthy worry in ground based gas turbine motors in light of NOx outflows . the propensity is to run incline, an identicalness proportion under 1, to diminish the burning temperature and in this way decrease the NOx discharges. The inclination is to run incline , an equilalence proportion under 1, to decrease the burning temperature and hence diminish the NOx emanations in any case, running the ignition incline makes it exceptionally powerless to burning insecurities

Some definitions

- **Air – Fuel [AF] ratio**

$AF = M_{air}/M_{Fuel}$

Where $M_{air=}$ mass of air in the feed mixture,

M_{fuel} = mass of fuel in the feed mixture

Fuel-Air ratio: $FA = M_{fuel}/M_{air} = 1/AF$

- **Air –fuel molar ratio**

$AFmole = N_{Air}/N_{fuel}$

Where $N_{air\,=}$ moles of air in the feed mixture

N_{fuel}= moles of fuel in the feed mixture

- **Rich mixture**

More fuel than necessary

[AF] mixture $[AF]_{stoich}$

Most combustion systems operate under lean conditions.

- **Equivalence Ratio**

Proportionality proportion demonstrates the deviation of a genuine blend from stoichiometric conditions

$$\emptyset = \frac{[FA]actul}{[FA]stoich} = \frac{[FA]stoich}{[FA]actual}$$

6.2 Governing equations

The equation for conservation of mass, or continuity equation, can be written as follows;

Continuity equation

$$\frac{\partial \rho}{\partial t} + \nabla(\rho\vec{v}) = s_m$$

Where is thickness , ui is the mean speed part in i directional the source term sm is the mass added to the nonstop stage because of vaporization of fluid beads . for the non-responding stream sm takes an estimation of zero .

Momentum equation;

$$\frac{\partial(\rho\vec{v})}{\partial t} + \nabla(\rho\vec{v}\vec{v}) = -\nabla p + \rho g + \vec{F}$$

Where p is static weight, g and f are gravitational body powers and outside body powers [e.g. powers that emerge from collaboration with the scattered phase], separately. F additionally contains other model-subordinate source terms, for example, permeable media and client characterized sources.

Energy equation;

$$\frac{\partial(\rho E)}{\partial t} + \nabla.(\vec{V}(\rho E + P) = -\nabla.\,\Sigma_j h_j j_j + s_h$$

S_h includes the heat of chemical reaction. In the above equation

$$E = h - \frac{p}{\rho} + \frac{u_1^2}{2}$$

Where sensible enthalpy h is defined for ideal gases as

$$h = \Sigma_j h_j m_j$$

Where m_j is the mass fraction of the species j and

6.3 TURBULENCE MODELING;

Turbulence flow has been modeled using the standard k-model.

6.3.1 INTRODUCTION

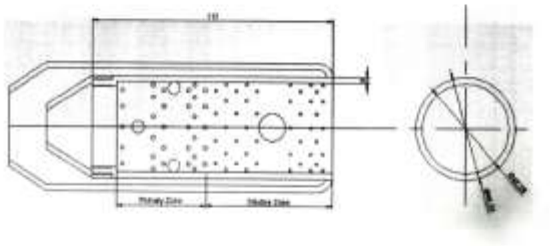
All liquid streams which we experience in day by day life are turbulent. Run of the mill cases are stream around [and in] autos, planes and structures. The limit layers and the wakes around and after feign, for example, autos, planes and structures are turbulent. Likewise the stream and burning in motors, both in cylinder motors and gas turbines and combustors, are exceptionally turbulent. Air developments in rooms are likewise turbulent, in any event along the dividers where divider planes are framed. Henceforth, when we process liquid stream it will no doubt be turbulent. Turbulent stream is unpredictable, random and averaged we can regard the stream as two-dimensional.

The initially transported variable is turbulent motor vitality k. the second transported variable in aces is the turbulent dissemination; the variable decides the size of the turbulence, though the primary variable k, decides the vitality in the turbulence.

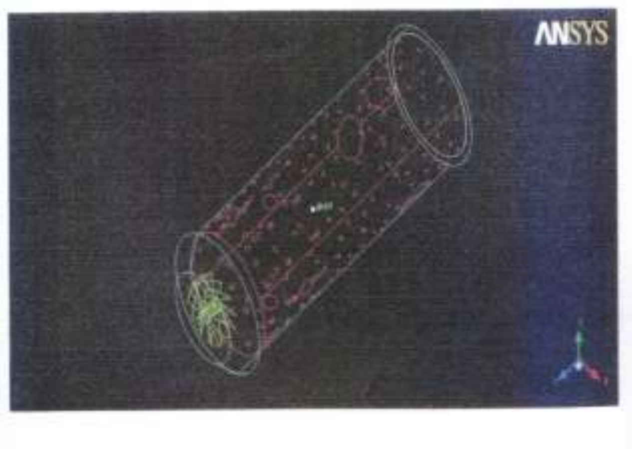
Geometrical modelling and grid generation

Design of micro combustor

- We have planned a turbular combustor utilizing CATIA V5R1 7, which is outlining programming.
- Using part workbench we planned the combustor.
- The explanation behind testing this kind of turbular combustor is because of high to high weight misfortune and example element contrasting with other sort of combustors.
- Our point is to lessen the example figure and weight misfortune this sort of ignition chamber.
- We lessen the example variable by changing the gaps in the liner packaging of our combustor



Outline of micro combuster



Geometrical Model Using ICEM-CFD

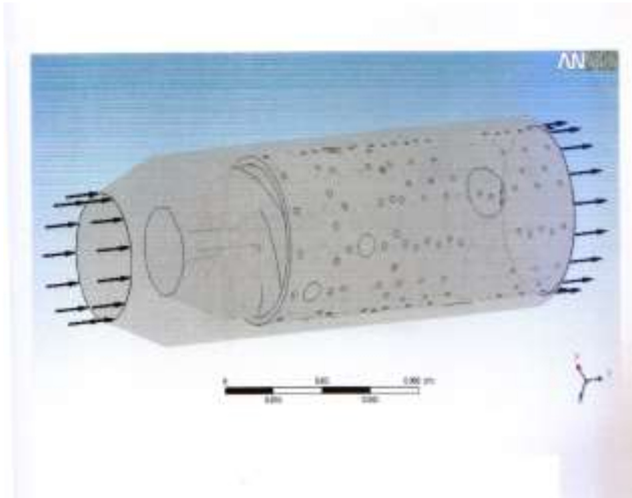


Fig Solid Model

Temperature Distribution

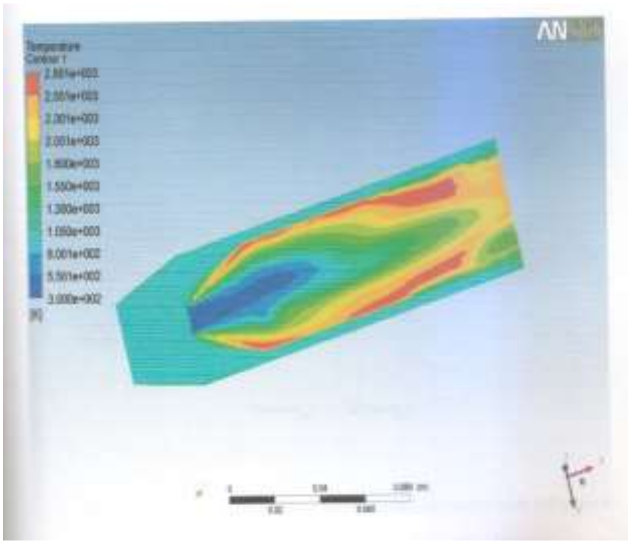


Fig 7.21 Distribution of temperature in micro-combustor with A/F ratio 60

Graphical Representation Of Temperature Variation

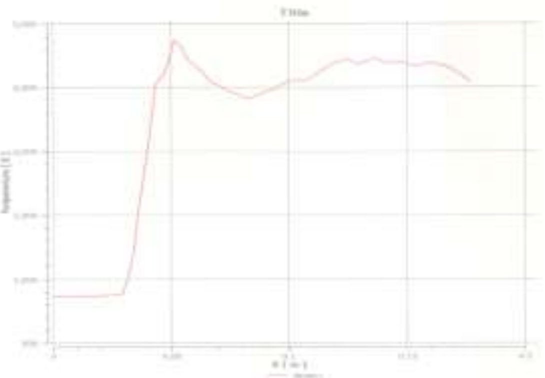


Fig Graphical representation of temperature variation in the Micro-Combustor with A/F ratio 60

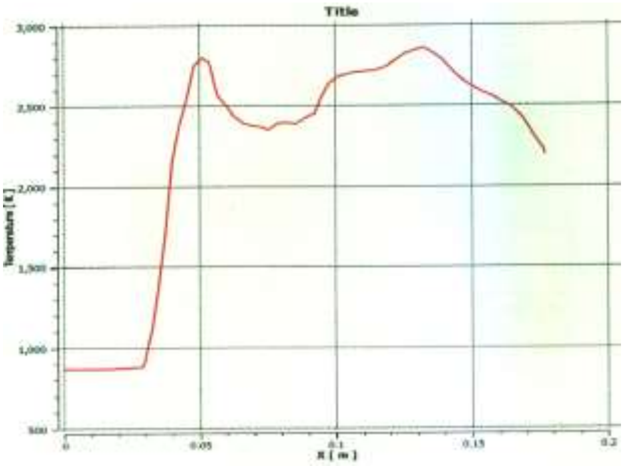


Fig Graphical representation of temperature variation in the Micro-Combustor with A/F ratio 80

From the above graphs it is unmistakably demonstrated that the temperature at the way out is less when the A/F proportion is 80 when contrasted with A/F proportion as 60.

CONCLUSION

The configuration of small scale gas turbine ignition chamber is completed utilizing hydrogen as fuel and the outline is then accepted utilizing Numerical and Experimental methodology. The subjective and quantitative assention of CFD results with the Experimental Results proposal that the essential suppositions and limit conditions and in addition the issue definition for CFD investigation can be connected to comprehend the stream marvels, temperature shapes and weight appropriation for burning chamber. The speed profiles demonstrate an expanding pattern along the length of ignition chamber, yet low speeds are experienced in essential zone which is helpful for burning security. The SST k – model were utilized to depict the liquid stream and cooling conduct of the combustor. The liquid stream in the tube can be for the most part isolated into reverse field in the combustor and influences the air appropriation through various air affirmation openings. High speed from essential and weakening air confirmation gaps is seen. Such high speed from the air affirmation openings guarantees high static weight drop, which is profitable in blending through air confirmation gaps.

SCOPE FOR FUTURE WORK

The accompanying recommendations could be considered as the continuation of the present work.

8.2.1 Device advancement

- Develop a gadget to gauge the fire temperature and fire thickness of the miniaturized scale combustors utilizing the fire temperature model proposed in the present study.
- Measure the convective warmth exchange coefficient from the fire to the miniaturized scale combustor inner divider, and associate the convective warmth exchange coefficient and the combustor tube breadth.
- Study the impacts of the pivotal warmth conduction inside the divider on small scale burning.

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