Analysis to Reduce Emission Characteristics for Gas Turbine Combustion

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ABSTRACT

The main aim of this paper is a determine to reduce emission characteristic for gas turbine combustion. In semi-empirical method of annular combustor design, there is a prediction for emission products (like nitrogen dioxide (NOx), carbon monoxide (CO), hydrocarbons (HC), smoke and residents) etc. To calculate the amount of emissions for flight operating conditions and landing takeoff condition where high radiation (NOx) occurred. In lean premix staged combustion, fuel and oxidizer (air) mixed before combustion at primary zone and it's entirely different from diffusion flame combustion because combustion takes place simultaneously mixing of fuel and oxidizer (air). So lean premixed staged combustion process is the best way to reduce emission to minimize equivalence ratio of primary zone of annular combustor, so that its control the emission. In this method, we control emission through reduce specific fuel consumption (SFC) at landing and takeoff cycle (LTO cycle) and fuel-air ratio compare with stoichiometric equation of fuel and oxidizer (air). The engine thermodynamic state is mainly determined by the thrust demand of the aircraft, the ambient conditions and different flight missions have to be considered. Therefore a flight performance module is presented by using the technique of lean-premix combustion to control the emission and to improve the performance of engine SFC.

Key Words: Gas turbine emission control, Gas turbine emission, Gas turbine combustion.

I INTRODUCTION

A typical lean premix staged (LPS) combustion can be dependent on the three main factor.

(a) Fuel injection
(b) fuel vaporization
(c) fuel air mixing

The function is to achieve complete evaporation and complete mixing of fuel and air before combustion. By eliminating droplet combustion and supplying the combustion zone with a homogenous mixture of low equivalence ratio, the combustion process proceeds at a uniformly low temperature and very little NOx is formed. The flame is stabilized by the creation of one or more recirculation zone, because combustion is completed in this region and emission will be low and it can be improved with variation of SFC. A useful by product of lean premix staged combustion is that essentially free from carbon formation especially when gaseous fuel are used, so LPS combustion is more appropriate.

II GAS TUBINE COMBUSTION PROCESS

In gas turbine combustion, there are three zones:

(a) Primary zone
(b) Secondary zone
(c) Dilution zone

In primary zone 85% combustion occurred rest of the combustion takes place in secondary zone. Burned gases chilled into dilution zone due to uniform temperature need and it's entered to the turbine section. Gas turbine combustion schematic diagram given in below.

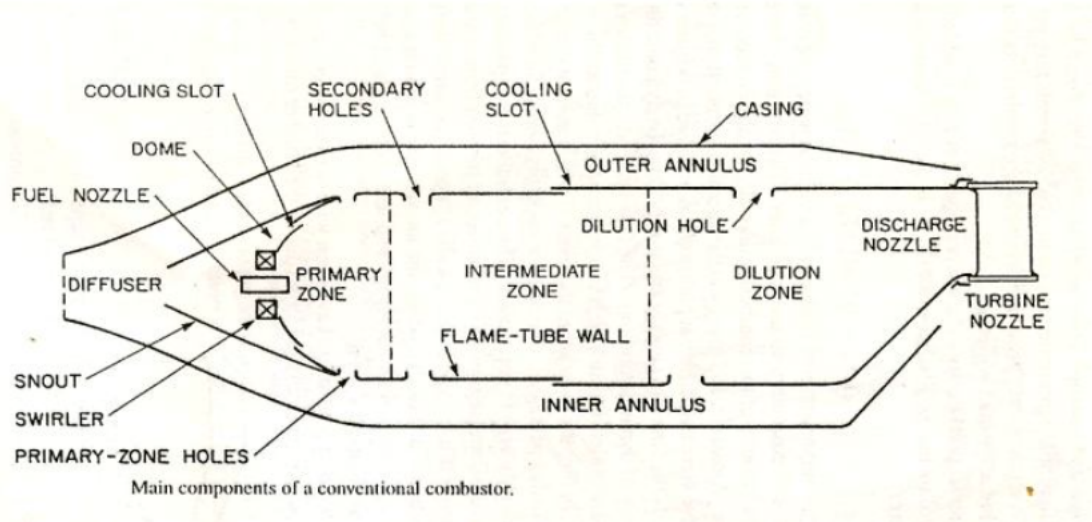

Fig. 1 Gas Turbine Combustion

III COMBUSTION EFFICIENCY

Combustion efficiency of gas turbine combustors should be very close to 100% if fuel and air are well mixed in proper proportions, ignited and given proper time to burn. In usual industrial application, these conditions are generally met. In the aero gas turbine engines, the combustor size is critical. It has always proven advantageous to design for operation near the limits of combustion intensity. Furthermore, aero engines combustor operates over a wide range of inlet temperatures, fuel-air ratios at flight altitudes with the result that the combustion performance may deteriorate at high altitude. Combustion efficiency of a gas turbine depends on various processes taking place in the combustor primary zone. Combustion taking place in the primary zone can be treated as three sequential processes: evaporation, mixing and chemical reaction. All these processes can be nominally expressed and be linked with combustion efficiency as a function of:

$$Efficiency = f(A/F)^{-1}\left[(Evaporation\ rate)^{-1} + (Mixing\ rate)^{-1} + (Reaction\ rate)-1\right]^{-1}$$

Combustion efficiency is defined as the percentage of available chemical energy in the fuel which is converted to heat energy within the combustor. Specific Fuel Consumption (SFC), the ratio of fuel consumption rate to net engine thrust, and total fuel consumption are both proportional to combustion efficiency.

$$\eta = \frac{T_p - T_a}{T^* - T_a}$$

Where,

T_p = Temperature of the Products of Combustion.
T_a = Temperature of the air.
T^* = Adiabatic Flame Temperature.

To make the analysis of the combustion process and for describing combustion efficiency, two approaches are most widely used, the burning velocity model and the stirred reactor model. The burning velocity model is commonly used in describing the combustion phenomena in a gas turbine combustor.

IV EMISSION CAUSE

The gas turbine engine emissions offer the greatest potential threats to the stratosphere are:-

(a) Water vapour and carbon dioxide which could produce a "green house effect" on the earth atmosphere.

(b) Sulfur compound leading to particulate formation, which could divert solar radiation away from the earth and removing sulfur at refinery

(c) Oxides of nitrogen, which could deplete the ozone layer and allow to increased penetration of solar u.v.rays.

(d) NO_x(NO, NO_2 and N_2O) emitted from combustion process is a atmospheric pollutants and its response for formation of ground level smokes and fine particle and heat radiation(radiate the pollution) to effects on respiratory system of human and animals and living organism.

Thus the emission of main interest is NO_x because its reaction with ozone in the atmosphere and to control of NOx emission is a world-wide concern. The reaction mechanism can be expressed as

$$NO + O_3 \rightarrow NO_2 + O_2$$

$$NO_2 + O \rightarrow NO + O_2$$

V REDUCTION OF EMISSION ON SPECIES

It has been the practice in the past design primary zones to operate at or above the stoichiometric mixture strength, to minimize combustor size and assist in ignition. Therefore a limit to the level of NO_X reduction can be achieved in this way.

For stoichiometric eq^n:

$$C_{12}H_{23}\ (Fuel) + [O_2 + N_2] \rightarrow CO_2 + H_2O + N_2$$

For lean mixture:

$$C_{12}H_{23}\ (Fuel) + 17.75\ [O_2 + 3.76\ N_2] \rightarrow 12\ CO_2 + 11.5\ H_2O + 3.76X17.75N_2$$

For Rich mixture:

$$n\ C12\ H_{23}\ (fuel) + [O_2 + 3.76\ N_2] \rightarrow CO_2 + H_2O + N_2 + O_2 + CO$$

Where n = nos. of moles of fuel

VI EMISSION REGULATION

The International civil Aviation organization (ICAO) has promulgated regulations for civil subsonic turbojet/turbofan engines with rated thrust level above 26.7kN (6000 pounds) for a defined landing takeoff cycle (LTO) which is based on an operational cycle around airports. This LTO cycle is intended to be representative of operation performed by an aircraft as it descends from an altitude of 914 m(3000 ft) on its approach path to the time it subsequently attain the same altitude after takeoff.

Emission emitted during the LTO cycle per kilo newton (KN) of rated thrust at sea level.

We have,

Emission (g/kN) = Emission index (g/kg fuel) X Engine SFC (kg fuel/hrkN) X Time in Mode (hr)

This equation shows that two methods are available to the engine manufacturer for reducing Nox. One is to make improvements to the combustor that reduce its emissions index (EI) and the other is to choose an engine cycle that yield lower SFC, because the CO and UHC level of modern gas turbine engine have been significantly reduced at all low power conditions and only Nox is emitted in appreciable amount at altitude cruise in practice the emissions generated by aircraft engine consist primarily Nox. The ICAO standard for smoke measurement is expressed in terms of a smoke number (SN), which is related to the engine takeoff thrust (F_{00}),

$$\mathbf{SN = 83.6\ (F_{00})^{-0.274}}$$

ICAO standards for gaseous emission are presented in below drawn table 1, which π_{00} is engine pressure ratio at takeoff and SN expression is shown graphically, shown given below.

Table1:
ICAO gaseous emissions standards

EMISION, g/kN	SUBSONIC TURBOJET/ TURBOFAN ENGINES	SUPERSONIC TURBOJET/ TURBOFAN ENGINES
HC	19.6	$140(0.92)\pi_{00}$
CO	118.0	$4550(\pi_{00})^{-1.03}$
NOx	$32+1.6\pi$	$36+2.42\pi_{00}$

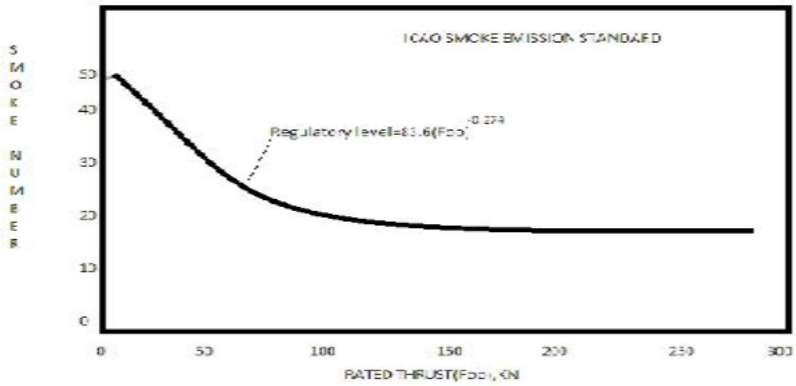

Fig.2 ICAO Smoke Emission Standards

VII METHODS OF EMISSION REDUCTION

The main factors controlling emissions from gas turbine combustion may be considered in following reason:-

(a) The primary zone temperature and equivalence ratio closer to around 0.8.

(b) The degree of homogeneity of the primary zone combustion process.

(c) Residence time in the primary zone (increase in primary zone volume).

(d) Liner wall quenching characteristics.

(e) Fuel rich primary zone designs.

(f) Improved fuel atomization process.

(g) To use Water injection

(h) Fuel staging

VIII APPROACHES TO THE DESIGN OF LOW EMISSION COMBUSTOR

To design the low emission combustor , improved in variable geometry like swirl of air fuel mixture and lean premix stage combustion in that flame blowout at lower power condition, so fuel consumption(combustion efficiency),durability, maintainability and safety consideration, must be taken into account in future application of lean premixed staged combustion techniques to engine combustors design.

IX CONCLUSION AND FURTHER WORK

The great potential of the LPS combustion concept for ultralow emissions combustors has led NASA to establish its stratospheric cruise emission reduction program. These programs will effective for all air-fuel ratio, there is a certain emission species value will get. Special emphasis is placed on achieving very low Nox emission level at stratospheric cruise conditions. Combustor operating (pressure, temperature and burning zone equivalence ratio), residence time, reference velocity, combustor and various fuel-air mixing characteristics, such as spray angle. The main objective is to examine the factors influencing the performance and emission characteristics of LPS combustion.

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