Accepted Manuscript

NOx reduction strategies in scramjet combustors

Antonella Ingenito

PII: S1270-9638(16)30917-8
DOI: http://dx.doi.org/10.1016/j.ast.2016.10.020
Reference: AESCTE 3806

To appear in: *Aerospace Science and Technology*

Received date: 3 September 2015
Revised date: 19 October 2016
Accepted date: 20 October 2016

Please cite this article in press as: A. Ingenito, NOx reduction strategies in scramjet combustors, *Aerosp. Sci. Technol.* (2016), http://dx.doi.org/10.1016/j.ast.2016.10.020

NOx reduction strategies in scramjet combustors

Antonella Ingenito*

Department of Mechanical and Aerospace Engineering, University of Rome "La Sapienza", Rome, Italy

* Corresponding author: Antonella Ingenito
Email address: antonella.ingenito@uniroma1.it
Tel: +39 3346068243

Abstract

The chance for future long range high speed commercial transport leads to a more comprehensive investigation of its environmental impact to ensure in advance that this development is sustainable. Although scramjet engines mostly use hydrogen as fuel consequently avoiding the particulate, CO and CO2 emissions, the high temperatures within these engines are critical for the NOx, water vapor and OH emissions. Altitudes associated with hyper/supersonic flight, i.e., 20000-30000 m, correspond closely to the maximum ozone density: there, NOx emissions can catalyze ozone destruction. Thus reduction of the NOx emissions remains of primary concern, being responsible for the ozone layer depletion. In this context, this paper investigates a strategy for the NOx reduction in supersonic combustion engines, in particular focusing on the impact of the combustor pressure and equivalence ratio on the nitrogen oxide emissions.

Keywords: NOx, Pollutants, Emissions, Hydrogen Combustion, High Speed Vehicles

Nomenclature

Acronyms

ICAO International Civil Aviation Organization
HSCT High-Speed Civil Transport
SST supersonic transport
EPA Environmental Protection Agency

Roman Symbols

A: Arrhenius constant
D: chamber diameter [m]
G: standard-state Gibbs free energy [kJ/mol]
P: pressure [atm]
T: temperature [K]
V: velocity [m/s]
E.R.: equivalence ratio

Greek Symbols

Φ fuel air ratio
ρ density [kg m^{-3}]
χ molar concentrations
Δ change

Superscripts and subscripts

0: standard conditions
i: condition of i-th species
p: pressure
af: adiabatic flame

M = Mach number
x_{inlet} = *combustor inlet*
$x_{ioutlet}$ = *combustor outlet*
V_{air} = inlet air velocity
Y = mass fraction
η = combustion efficiency

1 INTRODUCTION

Until rather recently, the environmental effects resulting from aircrafts exhaust have been a minor topic in the general debate on the environment. The current renewed interest in the development of hypersonic vehicles for intercontinental flights or for lifting to orbit, like Sänger [1], NASP [2], or the LAPCAT II [3] conceptual vehicle makes the investigation of environmental effects a must [4, 5].

Emissions of aircrafts generally include carbon dioxide (CO2), water vapor (H2O), nitrogen oxide (NO), nitrogen dioxide (NO2), carbon monoxide (CO), a variety of hydrocarbons (HC), sulphur oxides, soot and other particles. During the last three decades numerous studies have focused on the different implications of NOx emissions from aircrafts [6,7,8, 9,10].

Different aspects of the impact of aircrafts emissions on the atmosphere have been identified, including changes in greenhouse gases, particles, contrails, and cirrus cloud formation [11, 12, 13, 14, 15].

The implication of NOx emissions on ozone levels depends strongly on the altitude where the emissions are released, for both chemical and dynamical reasons. In fact, the altitude at which NOx emissions take place is critical to determining their impact.