Analyzing Concentric Flow Slot Burner for Stabilizing Turbulent Partially Premixed Flames of Gaseous Fuels

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1 Introduction

The combustion of gaseous fuels in turbulent partially premixed flames with inhomogeneous mixtures is a common phenomenon in many practical applications, such as gas turbines, internal combustion engines, and industrial burners. However, the flame structure and stability of these flames are complex and challenging to understand and model, due to the interactions between turbulence, chemistry, and mixture fraction fluctuations. Therefore, there is a need for experimental and numerical investigations of these flames using advanced techniques and tools.

The objective of this project is to analyze the physical parameters for the design of a concentric flow slot burner (CFSB) for stabilizing turbulent partially premixed inhomogeneous flames of gaseous fuels and look for the possible materials to be used for manufacturing the burner. The CFSB is a modified design inspired by the Wolfhard-Parker slot burner that allows creating planar turbulent flames with different levels of mixture inhomogeneity at the burner exit.

2 Flame

A flame is an area of bright burning gas during a highly exothermic chemical reaction taking place in a thin zone. Flames are categorized into various categories for their proper study. one of the major classifications is on the basis of the composition of fuel and oxidizer mixture.

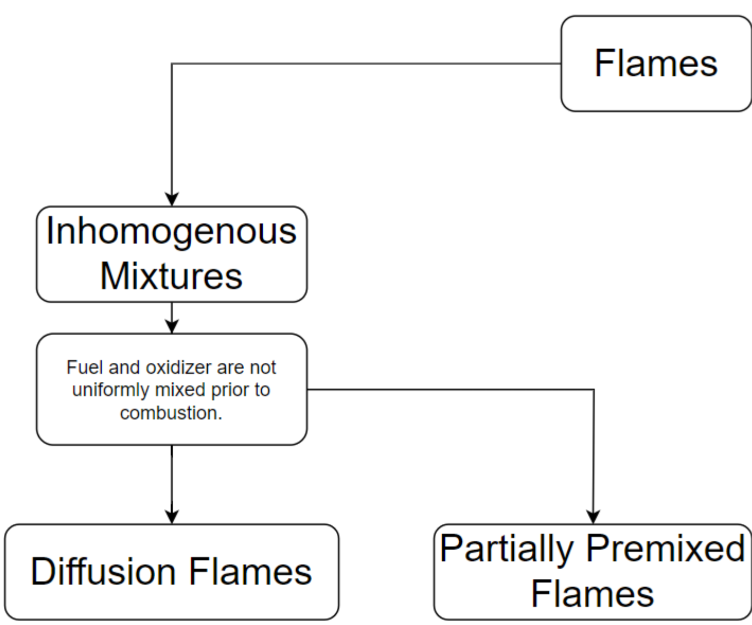
Stabilised Turbulent Flames: It refers to a combustion process in which a flame is maintained and sustained in the presence of turbulent flow conditions.

Equivalence Ratio(Φ): The equivalence ratio Φ of a premixed combustion system is defined as the ratio of the actual fuel-to-oxidizer mass ratio to the stoichiometric fuel-to-oxidizer mass ratio.

Reynolds Number(Re): Reynolds number is a dimensionless quantity that is used to determine the type of flow pattern as laminar or turbulent while flowing through a pipe. It is defined by the ratio of inertial forces to that of viscous forces.

$$Re = \frac{\rho u L}{\mu} \tag{1}$$

ρ = Density of the fluid, u = Flow speed, L = Characteristic linear dimension of flow tube, μ = Dynamic viscosity of the fluid



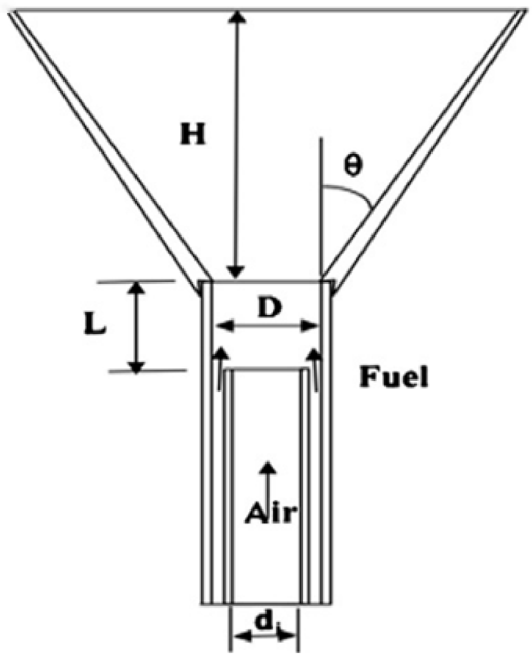
3 Burner Design Parameters

The main aim of the design of the burner is to be relatively simple for manufacturing along with being able to generate highly stabilized turbulence flames. Also, the main motive is to reduce the curvature effect of jet flames from circular or rectangular nozzles.

The outer tube, known as fuel tube, carries fuel (typically natural gas or propane) to the burner. The fuel is usually under pressure, and it enters the burner through small holes or slots along the length of the tube. These holes or slots are designed to deliver the fuel in a controlled manner, creating a uniform distribution of fuel along the burner.

The inner tube, known as the air tube, is surrounded by the fuel tube and is responsible for delivering the combustion air to the burner. The air tube has openings or slots through which the air enters, surrounding the fuel as it flows out from the fuel tube. The air and fuel mix together in the combustion zone, creating a proper air-fuel ratio for efficient combustion.

Design Specifications:



Here the characteristic dimensions are

L: Mixing Length in mm,

H: lift-off Height in mm,

d_i: Diameter of the inner slot for the passage of air

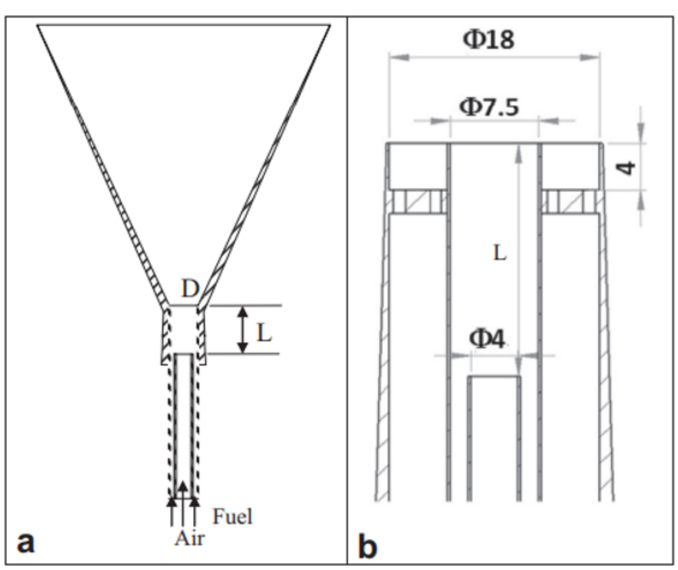
d_0**:** Diameter of outer slot for the passage of fuel

D: Hydraulic Diameter in mm

Θ**:** Cone Angle in radians

Here L is the mixing length which signifies the area provided for the mixing of the fuel and oxidizer mixture (air in this case)
For non-premixed flames (inhomogeneous flames): L=0
For fully premixed flames: L= sufficiently large value

An example of physical parameters is shown



4 Burner Design Materials

4.1 Fuel Tube & Air Tube

Stainless steel alloys like 304, 316, and 310 are commonly used for fuel tubes due to their high-temperature resistance and good corrosion resistance.

Carbon steel air tubes can be used if protected with appropriate coatings to prevent corrosion at high temperatures. Thermal spray coatings, ceramics, or refractory coatings can be considered.

Refractory metals such as tungsten and molybdenum have high melting points and can withstand high temperatures. However, they can be brittle and challenging to work with.

4.2 Nozzle

To understand and study the flame profile we must be able to observe it and thus to aid in the procedure we will look for transparent materials that can match the nozzle demands.

Quartz is a transparent material with good thermal stability and resistance to thermal shock. It can withstand high temperatures, making it suitable for applications where visibility is needed. However, prolonged exposure to extreme temperatures and certain chemical environments may affect its properties.

Glass-ceramics are materials that combine properties of both glass and ceramics. Some glass ceramics can have transparency properties and reasonable thermal resistance.

5 Conclusion

Through various research papers and studies available and as mentioned in the references, we successfully defined the important physical parameters and their effects on model and tried to look at some of the possible materials that can be used to manufacture a Concentric Flow Slot Burner.

6 References

- A concentric flow slot burner for stabilizing turbulent partially premixed inhomogeneous flames of gaseous fuels
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