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RESEARCH PAPER

Temperature measurement for hydrogen gas in turbulent jet diffusion flame with swirler of angle 45°

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ABSTRACT

Temperature measurement of H_2 gas was investigated experimentally in turbulent diffusion flame with co-flowing air stream with swirler. The air velocity changes from slow to high flow rate. Reynolds number is varying throughout the process from laminar to turbulent region. Results showed that the temperature decreases with increase the air flow rate and also temperature decreases as decrease in M.F.R. and equivalence ratio. Flame stability increases with increasing the hydrogen content in the hybrid fuel mixture.

Key Words : Hydrogen gas, Temperature, Flame

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In the past few decades, hydrogen has received increased attention as a potential alternative for fossil fuel based power generation. It has the advantage of not emitting hydrocarbon-generated pollutants like CO, CO_2, SO_X, etc. as it carries no carbon or any other elements with it. Apart from the above-cited positive aspects, there is another compelling reason for reducing the use of fossil fuels *i.e.* the limited supply and high global demand. The most possible solution to this problem now is to use hydrogen as an energy carrier. Moreover, hydrogen has 2.6 the energy per unit mass as compared to that of the gasoline. Hydrogen possesses superior characteristics to any other hydrocarbon fuel in terms of ignitability, low ignition delay, and higher Flame stability. However, its higher flammability and lower *volumetric* energy density make the on-board storage system complicated for both ground.

The flame structure is characterized by temperature. Temperature is an important parameter for developing a hydrogen burner. The flame can be divided by three zones, 1. Preheat zone 2. Reaction zone 3. Recombination zone. The preheat zone in which heat release is very small. Chemical reactions are takes place with fuel air mixture in reaction zone. In this zone, chemical energy in the form of heat is being released and decomposition of hydrocarbon fuel involving several chemical reactions take place and intermediate like H_2, CHO, H, OH, are consumed. The recombination zone is one in which recombination reactions involving radicals occur leading to formation of CO_2 and H_2O. There is no heat release in this zone.

RESEARCH METHODOLOGY

Swirler design :

Swirling flow is commonly used in gas turbine combustors to create a recirculation region for flame anchoring and to promote mixing between fuel and oxidant so that efficient burning can be accomplished in the shortest possible distance. Many different designs are used; some swirl the fuel jets, some swirl the secondary air jets, some swirl both jets in the same direction, while others swirl the jets in opposite directions. Although swirling is found to be most effective in accomplishing the design objectives of combustors, a systematic way of designing swirler is not available. Consequently, swirler design for combustors has to be carried out on a trial-and-error basis. The reason for this is a lack of understanding of the fluid dynamics of confined swirling flow, especially concerning the mixing of different density fluids in a non-reacting as well as a reacting environment. The design of swirler is depends its vane angle and diameter. The inner and outer diameters of swirler were 12 mm and 30 mm, respectively and the vane angles of swirler were 0^0, 24^0, 45^0 and 60^0 in our purpose.

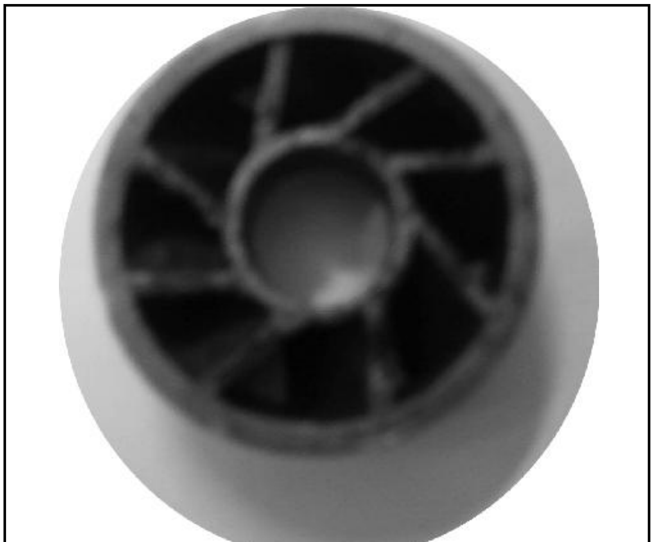

Fig. A : Swirler diagram

Experimental setup :

Fig. A shows a schematic of the experimental setup developed to study the in flame temperature of H_2 air flame. The hydrogen fuel was being supplied through a central tube which was made up of stainless steel while the swirling air flow was provided by a coaxial annulus. Air swirl motion was imparted through an axial plus tangential air entry variation of relative amounts of axial and tangential flow controls swirl strength. The hydrogen rotameters 10-100 LPM and 20-200 LPM are used which is provided by CVG company and also air rotameters are 20-200 LPM and 100-1000 LPM are used which is also provided by CVG Bombay. The 10-100 LPM and 20-200 LPM of hydrogen rotameter and 20-200 LPM air rotameter provided by CVG Ltd., Bombay. All tests were performed at ambient pressure and ambient temperature. The available inclinations of the vanes for swirler were 0^o, 24^o, 45^o and 60^o. In our study, the data is taken in 45^0 vanes swirler.

The following Fig. A and B has shown the rotameter for measuring the flow rates for hydrogen and air. Air enters through the three meshes and flow rate of air have measured by rotameter. There are four port available on the burner. Temperature has measured in thie port through R type thermocouple. Burner configuration and burner specification is given below in the form of diagram.

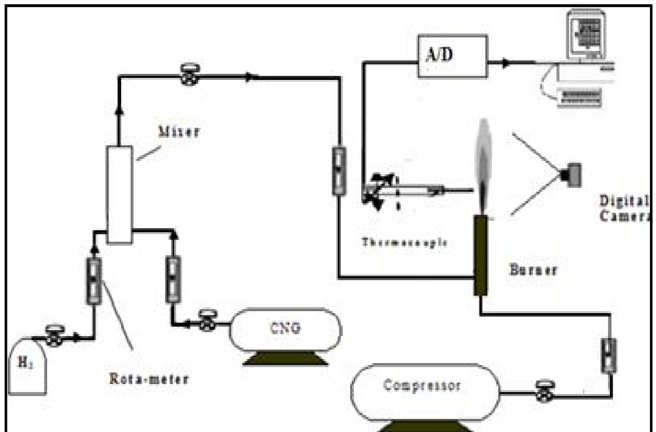

Fig. B : Systematic diagram of burner with temperature probe

The flow rates of hydrogen were taken as 28-140 LPM which corresponds to a power output of 5 – 25 kW at 0.98 combustion efficiency. Air flow rates were varied from 20 LPM to 400 LPM for each of the flow rates of hydrogen with the readings being taken as stoichiometric proportion of air flow rates. The stoichiometric proportion of hydrogen and air flow rates is 1:2.373 as LPM unit.

The enclosure made a stainless steel cylinder of inner diameter 80 mm and outer diameter 90 mm. The height of the cylinder was 420 mm and distance between two ports of cylinder was 100 mm.

The readings were taken both for swirled air flow and non swirled air flow. A Pt/Pt–13 per cent Rh rotameter is

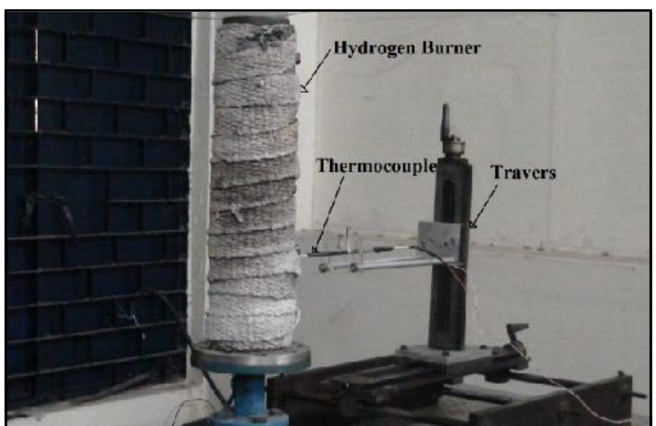

Fig. C : Burner photographs by central camera

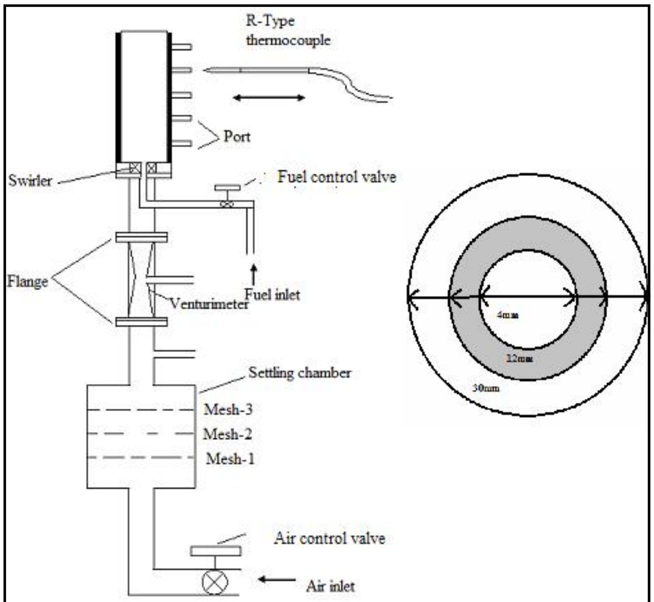

Fig. D : Burner configuration and burner specification with port

used for the temperature measurements with least count of 0.1mm. The thermocouple bead of 350μm diameter is coated with alumina to eliminate catalytic reactions. The maximum temperature is taken as 1800 K approximately. For taking the readings, 10-100 LPM and 20-200 LPM hydrogen rotameter is used. The arrangements of rotameters are given below in Fig. E.

Fig. E : Rota meters for measuring flow rates for hydrogen and air

RESULTS AND REMONSTRATION

Various temperature data have taken with various hydrogen flow rate (28 LPM, 85 LPM, and 140 LPM) and air flow rates 50-400 LPM. Temperature increases at various radial positions. The maximum temperature is 1850 K at port 3 (85 LPM hydrogen and 400 LPM air). According to Fig. 1, 2, 3 and 4 temperature of various radial position increases from 0 to 40 mm due to temperature is maximum at the midpoint of the burner in radial position.

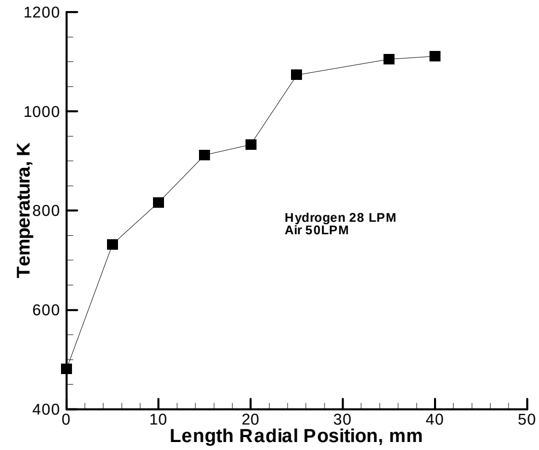

Fig. 1 : Temperature in radial position at 28 LPM and 50 air

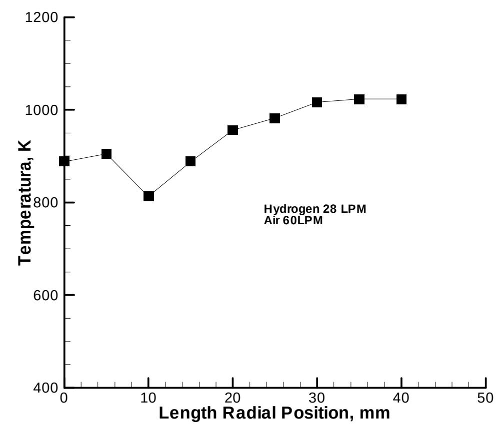

Fig. 2 : Temperature in radial position at 28 LPM and 60 air

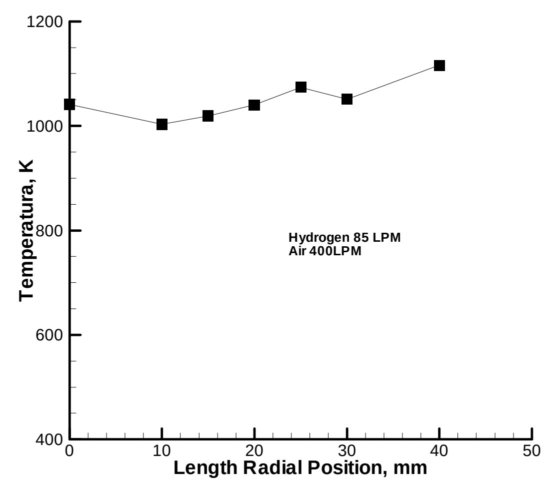

Fig. 3 : Temperature in radial position at 85 LPM and 400 air

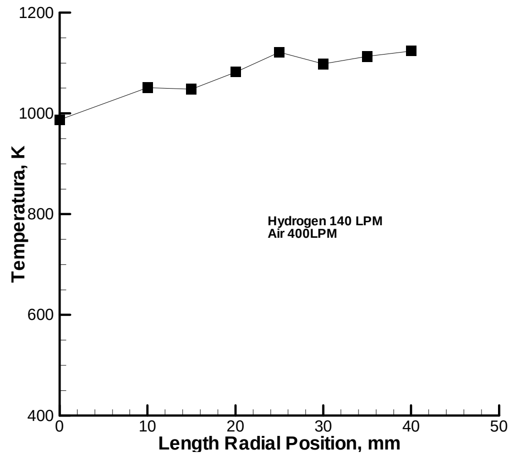

Fig. 4 : Temperature in radial position at 140 LPM H_2 and 400 air

Temperature in the port :

According to Fig. 5 and 6, Temperature increases from port 1 to port 3 and decreases from port 3 to port 4. This explains that the temperature was maximum in port three due to flame and temperature from port 3 to 4 decreases due to more heat loss.

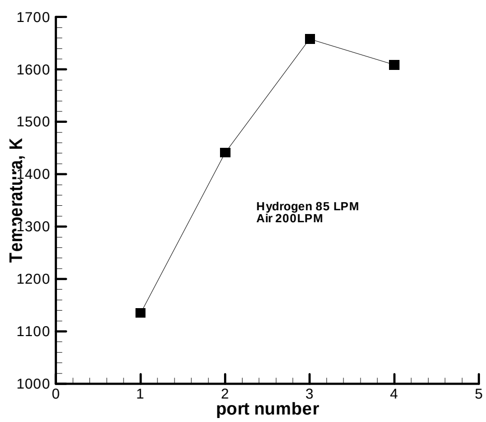

Fig. 5 : Temperature in ports at 85 LPM $H_2$and 200 LPM air

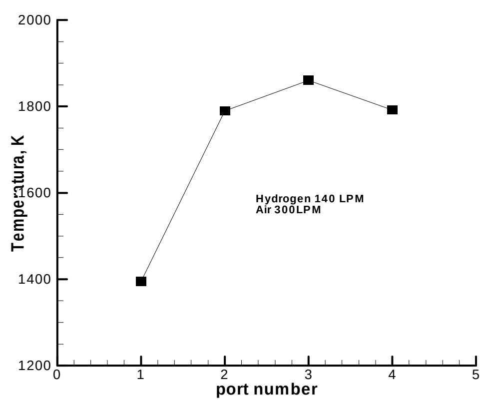

Fig. 6 : Temperature in radial position at 140 LPM H_2 and 300 LPM air

Conclusion :

It is observed that at port number 1 to 3 the temperature increases while at port number 4 the temperature gradually decreases for 85 LPM H_2 and 200 LPM air and 140 LPM H_2 and 300 LPM Air. Hence, temperature will maximum at port number 3. The maximum intensity of temperature cannot in near the burner. Flame always propagates upper side of the burner. Intensity of the flame, if going upper side, decreases. So the temperature of the third port was greater than fourth port. It was also observed that the increasing the length in radial position, temperature increases for 28 LPM and 50 Air, 28 LPM and 60 Air, 85 LPM and 400 Air, 140 LPM H_2 and 400 LPM Air. The temperature of midpoint of the radial position is greater than the near to the port due to flame temperature at mid point is maximum than other side. As the upper side of the atmosphere, the air (oxygen) deceases. So the premixed flame cannot be worked properly in the upper side of atmosphere. Hence, diffusion flame will be a solution of that problem. So the study of temperature for diffusion flame is important for the purpose.

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