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Parametric Analysis of Temperature Field of Syngas Impinging Burners

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ABSTRACT: In this study temperature and flame structure of synthetic gas of two impinging slot burner have been investigated experimentally by interferometry method. The main objective of the study was to examine the key parameters including Reynolds number of jet flow and input fuel and their equivalence ratio on combustion. For the first step, the experimental results of temperature distribution have been compared with measured data by thermocouples and maximum and minimum error of 8% and 3% were observed. Temperature Contour and temperature distribution in different sections have been extracted and analyzed. The results show that although the Reynolds number does not effect on the maximum temperature, it has a great influence on the flame structure. Thus, increasing the number of Reynolds increases the region of reaction in the line of symmetry, increases the number of Fringe lines and extends the heated region. Changes in the equivalence ratio directly affect the structure of the flame, thus an increase of this parameter shifts the flame zone to downstream and flame stability decreases.

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1- Introduction

Synthesis gas is considered as an alternative to fossil fuels in the research literature, naturally produced under special conditions by separating the chemical composition of wood and corn, including the combination of hydrogen and carbon monoxide and lower amounts of methane and other hydrocarbons. In the synthesis gas, the ratio of hydrogen to carbon monoxide value indicates the amount of energy capacity. On the other hand, the type and shape of the burners (rectangular, circular, etc.) have a great influence on the quality of the combustion. Premixed burners are widely used in the industry, such as melting units, industrial ovens, and home appliances. To increase the heat transfer rate, various methods, such as parallel, counterflow and impinging burners, have been widely used. The literature survey [1-6] shows that, the flame structure in impinging burner is a function of operating conditions and different geometric parameters. Although the behavior of multiple burners has been investigated in previous studies, but the effect of Reynolds number and the equivalence ratio on the flame structure and the temperature field in impinging burners is not investigated yet. In this study, the impinging flame of two slot burners is investigated experimentally by interferometry method and the results are reported and analyzed in the form of isotherm lines.

2- Experimental Setup and Methodology

The impinging burners are designed to be adjustable in terms of height, distance, and angle of incidence, as shown in Fig. 1. Each slot is made of two non-corroded stainless steel plates with a depth of 60 mm, sealed with a copper strip and a thickness of 0.1 mm, producing a 0.7 × 20 mm cross-section. To reach the fully developed flow at the exit of the burner, there is a honeycomb in the center of the nozzle. The emitted beam from He-Ne laser (5mW, 632.8 nm) is divided into 2 beams, one of them passes through the flame, and again the beams are merged and finally hits to the CCD digital camera. The patterns in the resulted Fringe pictures originate from difference between phases in two beams, originally caused by difference in refractive index in combustion products and air. Every bright and dark fringe line has the same phase information.

Local fringe number ($n(x,y)$) is calculated by image processing module of MATLAB software and finally temperature field is calculated by the below equation which is derived by Gladstone-Dale approximations.

$$T\left(x,y\right)=\left[\frac{n_{\infty}-1}{n\left(x,y\right)-1}\right]T_{\infty} \qquad (1)$$

In equation6, $T(x,y)$ is the local flame temperature and T_{∞} is ambient temperature which is maintained at 300 K during all the experiments as well as the ambient pressure on the 0.87 bar. The equivalent hydraulic diameter for calculation Reynolds number is derived from the following Equation:

$$D_H=\frac{4Lt}{2\left(L+t\right)} \qquad (2)$$

Error sources for this experiment are dislocation of thermocouples (which cannot be located at the exact position), difference in combustion products refractive index and flow measurement tool (4 percent according to manufacturer declaration).

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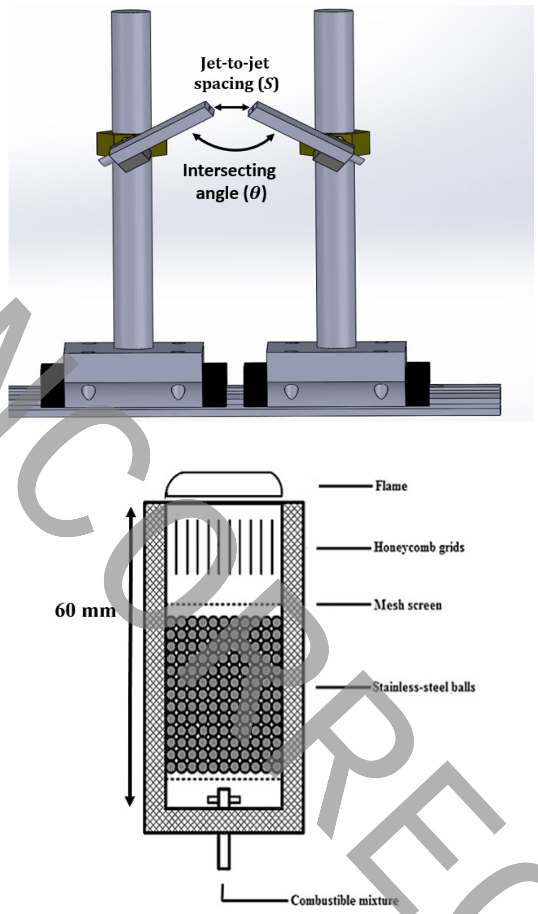

Fig. 1. Burners configuration and honeycomb structure

3- Results and Discussion

As shown in Fig. 2, in impinging flames, the flow regime is divided into four main regions: the inner region, the annular vortex region, the flash back zone and the recirculation zone. The inner area consists of pre-mixed species that have not yet entered the combustion process and are precisely located at the outlet of the nozzles. It is concluded that the size of this zone increases with the increase in the equivalence ratio. Due to the upward direction of the flow, the annular vortexes come out from outer regions of the flame, causing the air to flow into the combustion environment. The flashback zone contains volumes of flow that are driven into downstream of flame areas. The recirculation zone results in cross-flows, leading to higher efficiency in the flame. Due to the reversal of the flow, the heat reaches to unheated species that results in higher combustion efficiency and more stable flames. According to the presented concepts, it can be concluded that the combustion characteristics are a function of Reynolds number, equivalence ratio, angle and distance between burners.

In the symmetry line of impinging burner, the pressure and fluctuations increase. In addition, the collision of two flow streams eliminates the horizontal component of the velocity and results in a more stable flame. Effect of Reynolds number on the temperature distribution is shown in Fig.3 for two different sections.

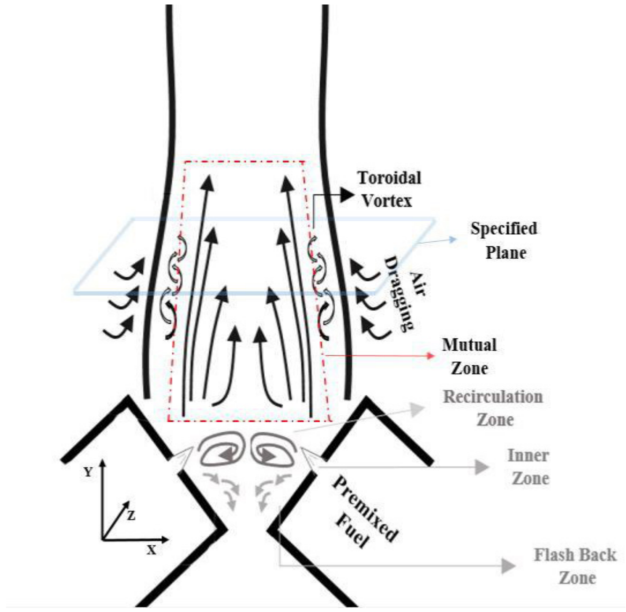

Fig. 2. Flow pattern generated by impinging burners

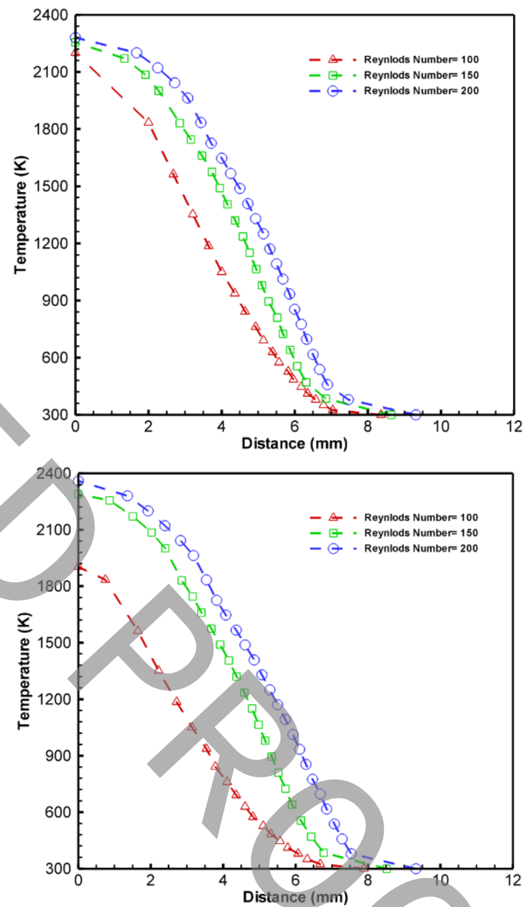

Fig. 3. Effect of Reynolds number on the temperature distribution, top: $\frac{y}{D_H} = 8$ and down: $\frac{y}{D_H} = 28$

4- Conclusions

In this study effect of Reynolds number and equivalence ratio on the impinging flames are investigated experimentally by interferometry method. The obtained results clarify that:

1-Although the Reynolds number does not have much effect on the highest flame temperature, it is very effective on the flame structure.

2- The increase in the equivalence ratio leads to the expansion of the flame in both dimensions, since in the higher fuel-to-air ratio, the greater tendency to drag the air into the flame is observed. The presence of buoyancy force leads to more instability on the upper sections.

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