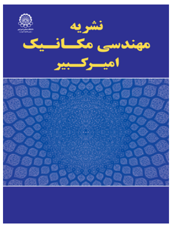

Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 52(6) (2020) 347-350
DOI: 10.22060/mej.2018.14064.5791

Numerical Study of the Flat Flame Burner Power Effect on the Producing Uniform Temperature Distribution in Cracking Furnaces

M. Mirbagheri[1], K. Mazaheri[1]*, E. Ebrahimi Fordoei[1], A. Alipoor[2]

[1] Mechanical Engineering Department, Tarbiat Modares University, Tehran, Iran.
[2] Mechanical Engineering Department, Shahid Chamran University, Ahvaz, Iran

ABSTRACT: In the present study, with the help of numerical study, the study of the uniform heat flux formation on process tubes as the main parameter in cracking furnaces has been investigated using flat flame burners with different thermal powers. Due to the lack of experimental data for solver validation, two problems of swirl burner and channel with conjugate heat transfer of combustion gases and solid surface have been used. To carry out simulations, the chtMultiRegionReactingFoam solver in OpenFOAM software has been developed by adding the conjugate heat transfer capability to the reactingFoam solver. In simulations, k-ω shear stress transport turbulence model has been used for turbulence modeling. The results of the simulations show that the use of a flat flame burner in cracking furnaces allows for the uniform temperature distribution in the furnace with the low maximum combustion temperature. Also, to create the appropriate heat flux around the pipes so that the proper temperature distribution for cracking reactions is provided, the minimum heat flux of the flat flame burners is required, which in less than that, the appropriate temperature distribution does not occur on the pipes.

Review History:

Received: 10 Feb. 2018
Revised: 23 May 2018
Accepted: 24 Jun. 2018
Available Online: 3 Jul. 2018

Keywords:

Cracking furnace
Flat flame burner
Benchmark problem
Heat flux
Combustion simulation.

1- Introduction

The use of combustion furnaces for the production of olefin is widely used in the petrochemical industry. The furnace consists of a radiation section (firebox), convection section and Transfer Line Exchangers (TLE) .The growing demand for olefin products, saving energy and control of emissions of pollutants is a strong incentive for further researches in the field of olefin producing technologies. In accordance with existing rules for reducing pollution, Gasser Hassan [1] developed a three-dimensional Computational Fluid Dynamics (CFD) model to simulate the turbulent diffusion flame on the fire-side of the radiation section of a thermal cracking test furnace coupled with a non-premixed low NOx floor burner. Different combustion models are used to simulate the turbulence–chemistry interactions for this flame.

One of the primary challenges in cracking furnaces is non uniform temperature distribution in firebox and producing hot spots on reactor tubes and increasing coke formation rate. Flat flame burner has a high ability to create a uniform temperature distribution in combustion chamber and in present study have been simulated a section of firebox equipped with flat flame burners to optimize furnace operation.

2- Geometry and Boundary Condition of Benchmarks and Cracking Furnace

Due to the lack of experimental results for the flat flame burners for solver validation, appropriate benchmark problems with experiment results have been used. In first a swirl burner [2] has been studied that is turbulence, non-premixed and with axial and tangential flame. Then for investigating conjugate heat transfer, a flow through the laboratory channel [3] has been choose and finally the cracking furnace was simulated. A schematic of the swirl burner used in this study is shown in Fig. 1.

The geometry of the burner is given in Table 1.

Velocity boundary condition in fuel and primary air follow equation 1 that different values for n, δ and $\overline{U}$ are presented in

Table 1. Burner dimensions

parameter	Dimension (mm)	parameter	Dimension (mm)
D_1	3.6	D_4	65
D_2	50	D_5	160.4
D_3	60		

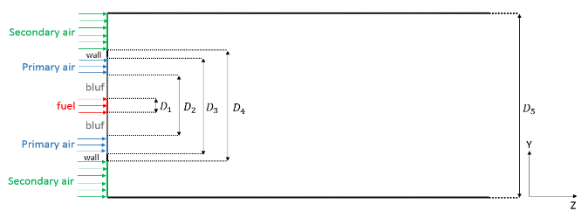

Fig. 1. Schematic of swirl burner

*Corresponding author's email: kiumars@modares.ac.ir

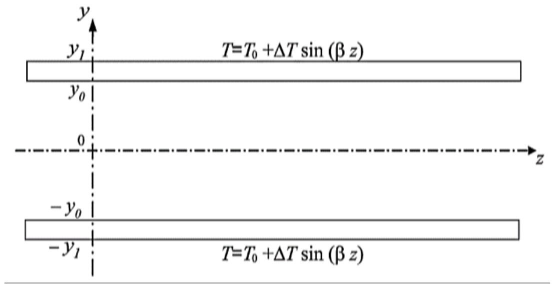

Fig. 2. Schematic of channel

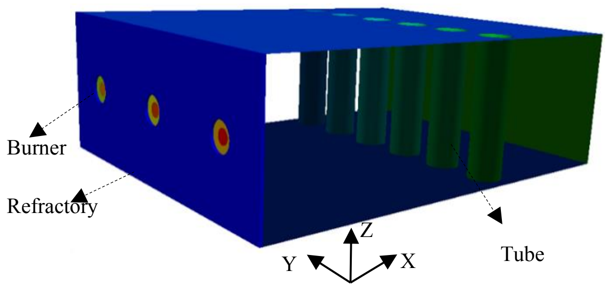

Fig. 3. Schematic of cracking furnace

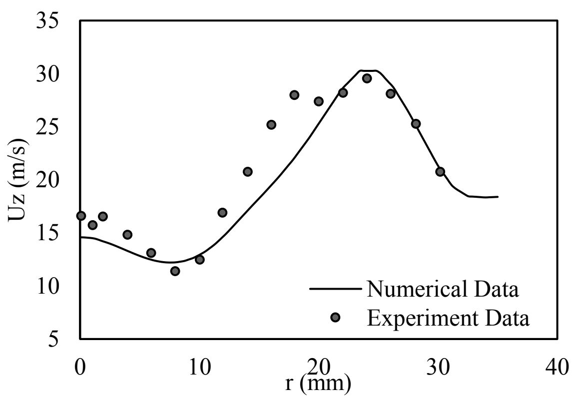

Fig. 4. Comparison numerical and experiment data

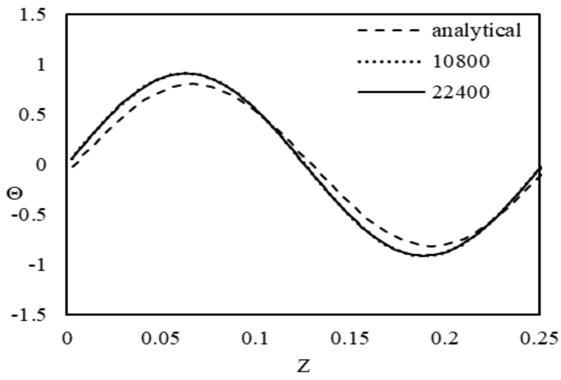

Fig. 5. Comparison numerical and analytical data

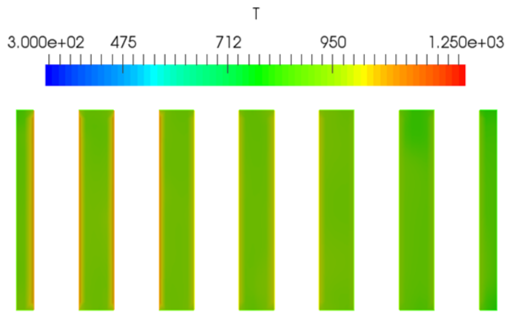

Fig. 6. Temperature distribution around the reactor tubes

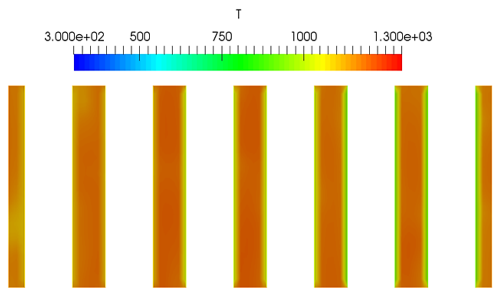

Fig. 7. Temperature distribution around the reactor tubes after increase burner power

Table 2 . Furnace dimensions

parameter	dimension (m)	parameter	dimension (m)
Height(z)	0.5	Tubes length	0.5
Length(x)	1.5	Diameter of tubes	0.12
Width(y)	1.2		

Table 3 . Burner boundary condition

Velocity (m/s)	burner		power burner	
	Fuel inlet	Air inlet	Fuel inlet	Air inlet
Axial	5	10	8	20
Tangential	2	4	4	8
Radial	5	20	20	30

the reference [4].

$$U = 1.218\overline{U}(1 - \frac{|y|}{\delta})^n \tag{1}$$

Schematic of simulated laboratory channel for validating conjugate heat transfer is shown in fig. 2. Channel input is presented in reference [5].

$$U_y = \frac{3U_0}{2}(1 - (\frac{y}{y_0})^2) \tag{2}$$

Firebox of simulated cracking furnace is shown in Fig. 3. The dimensions of this furnace are described in detail in Table 2. Three flat flame burners at a distance of 0.4 (m) located on the walls of furnace refractory.

3- Governing Equations and Numerical Solution

The governing equations include mass, momentum, energy and species conservation. Present simulation done with reactingFoam solver in OpenFOAM software.

4- Results and Discussion

For swirl burner, the numerical results are compared with the experimental data at the (z=60 mm) section, as shown

In channel, to validate the results, the non-dimensional number θ defined in Eq. (3) is compared with the analytical results in the intersection (y=20mm). As shown in Fig. 5, good agreement between analytical and numerical results is obtained

The results obtained from the simulation of the cracking furnace show uniformity of the temperature around the reactor tubes in Fig. 6, whereby temperatures 950 (K) around the tubes are observed. While ideal value for most cracking furnaces, it should be about 1200 to 1300 (K).

Average temperature was lower of average temperature in the optimal operation of the furnace. So with increasing fuel flow, the heat power of the burners increased. Table 3 shows boundary condition after increase power burner. In Fig. 7, the distribution of temperature around the tube after the increase in the power of the burners is presented that shows the uniformity and ideal of the temperature around all reactor tubes.

5- Conclusions

In order to simulate the cracking furnace, swirl flame and conjugate heat transfer phenomena have been studied, the results are compared in both issues with experiment data and there was a good match. Then the numerical simulation of cracking furnace was done. According to the results, the temperature uniformity of the reactor tubes was obtained first, but the challenge caused by the low temperature in comparison with the ideal temperature in the cracking furnace, which was followed by increasing the momentum at the burners.

References

[1] G. Hassan, M. Pourkashanian, D. Ingham, L. Ma, P. Newman, A. Odedra, Predictions of CO and NO x emissions from steam cracking furnaces using GRI2. 11 detailed reaction mechanism–A CFD investigation, Computers & Chemical Engineering, 58 (2013) 68-83.

[2] E.J.F. Flame, Flame interaction and rollover solutions in ethylene cracking furnaces, Gas, (2013) 1.

[3] A. Masri, S. Pope, B. Dally, Probability density function computations of a strongly swirling nonpremixed flame stabilized on a new burner, Proceedings of the Combustion Institute, 28(1) (2000) 123-131.

[4] A. Barletta, E.R. di Schio, G. Comini, P. D'Agaro, Conjugate forced convection heat transfer in a plane channel: Longitudinally periodic regime, International Journal of Thermal Sciences, 47(1) (2008) 43-51.