SIMULATION OF THE CROSSWIND AND THE STEAM ADDITION EFFECT ON THE FLARE FLAME

WUSNAH[1]*, YUNARDI[2], NOVI SYLVIA[1], ELWINA[3], YAZID BINDAR[4]

[1] *Chemical Engineering Dept., University of Malikussaleh, Lhokseumawe*
[2] *Chemical Engineering Dept., Syiah Kuala University, Banda Aceh*
[3] *Chemical Engineering Dept., State Polytechnics of Lhokseumawe, Lhokseumawe*
[4] *Energy and Processing System of Chemical Engineering Dept., Faculty of Industrial Technology, Bandung Institute of Technology, Bandung*
**Email : wusnah@yahoo.com*

Abstact

This paper presents the results obtained from the application of computational fluid dynamics (CFD) to modelling the crosswind and steam addition effect on a turbulent non-premixed flame. A pre-processor software GAMBIT was employed to set up the configuration, discretisation, and boundary conditions of the flame being investigated. The commercial software Fluent 6.3 was used to perform the calculations of flow and mixing fields as well as combustion. Standard k-ε and eddy dissipation models were selected as solvers for the representation of the turbulence and combustion, respectively. The results of all calculations are presented in the forms of contour profiles. During the investigation, the treatment was performed by setting a velocity of fuel at 20 m/s with varied cross-wind velocity at 3.77 m/s, 7.5 m/s and 10 m/s, and steam/fuel ratio at 0.14, 0.25 and 2.35. The results of the investigation showed that the standard k-ε turbulence model in conjunction with Eddy Dissipation Model representing the combustion was capable of producing reliable phenomena of the flow field and reactive scalars field in the turbulent non-premixed flame being investigated. Other results of the investigation showed that increasing the velocity of the crosswind, when the fuel velocity was kept constant, significantly affected the flow field, temperature and species concentrations in the flare flame. On the other hand, when the velocity of the fuel was varied at the constant crosswind velocity, the increasing velocity of the fuel gave positive impact as it enabled to counteract the effect of crosswind on the flare flame. The velocity of the crosswind very influence of combustion efficiency, from result of the investigation showed that increasing the velocity of the crosswind significantly affected the combustion efficiency, other result of the inverstigation showed that steam addition will very influencing combustion, excelsior the steam/fuel ratio results the combustion efficiency decrease.

Key words: CFD, steam addition, turbulent non-premixed flame, standard k-ε, eddy dissipation model.

Introduction

The flame characteristic of a chimney in stable (calm) atmosphere condition was very different when it windy. In some research (Fairweather and friends, 1992; Sinai, 1994; and Jhonson, 2000) showed that wind in high speed on the chimney lowering the combustion efficiency. In addition, a flame will be bend into the wind with smaller size of the flame so diffused oxygen is getting smaller. With the decline in the supply of air into the flame, it caused imperfect combustion and produces more unwanted pollutants.

The efficiency of a flame is considered to be equal to the combustion efficiency. The magnitude of the total CO2 fraction of burning flame expressed as flare flame efficiency, it strongly influenced by some different operating conditions and design conditions. The flame efficiency and gas emissions sometimes changed because of the differences conditions. One of it was the changed of wind velocity. In general, the flame of a chimney known have >95% efficiency of combustion. However, the impacts of wind velocity for the efficiency of chimney flame and emissions results are still studied by the researchers, both in the experimental and computational. Researched by Johnson and Kastiuk (2000) showed that the combustion efficiency of chimney was depending on the velocity of wind on the chimney surface. Decline combustion efficiency could barrier with increase the velocity of output fuel. It was the result of their experimental research study on a chimney with diameter 37.2mm. Whether it can proved in a simulation, its need further research.

From Wusnah (2011) researched known that the wind velocity greatly influence the produce of flare flame where it effects the result of combustions released into the atmosphere also, but if an additional of steam whether reduce the negative impact happened because of the influence of wind velocity where the additions of steam aim to reduce the impact of smoke from hydrocarbon combustion, therefore this research done to answer the question above.

The additions of steam to flare aimed for if while sometimes the emergence of soot on hydrocarbon combustion in the flare then the steam would reduce soot formation itself. Steam known as a method to increase the momentum, it also can pressing the formation of shoot thus reducing the number of pollutants from the combustion process in the chimney. The addition of steam in a certain ratio can improve the efficiency of combustion (Areas,2006). Wusnah (2011) researched explain that crosswind velocity more than 3,77 m/s at velocity of fuel 20 m/s, the flare flame structure strongly influence by crosswind and because of that the not combustion was windblown. Because of that, its need to know the influence of steam addition in that condition to reduce smokeless flare in order to not polluted the environment.

From this research known that the variety of wind velocity and addition of steam, against the flame that produces both qualitative as well as quantitative. To achieve it, a stimulation model of computational fluids dynamic used to show and analyzed the influence of cross-wind velocity and addition of steam against the efficiency of combustion produced.

Simulation Methodology

The geometry of a flare flame was considered to be similar to a nozzle in which a fuel was issued into atmosphere and burnt. Figure 1 showed the configuration of the geometry of the domain of calculation drawn using Gambit mesh generator where the nozzle is located at the bottom of the domain.

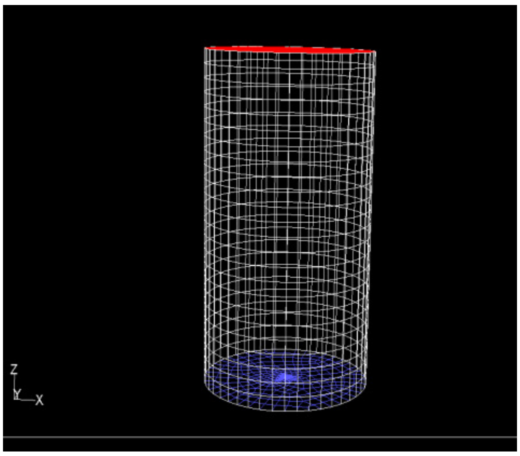


Figure 1. Three-dimensional Geometry of the flare flame domain

The flow field calculation was performed using Fluent 6.3 (Fluent. Inc., 2005) CFD ware of which serves as a processor as well as post-processor, with standard k-ε selected to represent the mixing fields. The fuel in this flame is assume to be propane. Upon the flow field calculation reaching convergence, the combustion calculation was started. The Eddy Dissipation Model (EDM) was selected to represent the reactive scalar field in the flame. Radiation resulted from the combustion was represented with a simple P1 model. The study was performed by setting a velocity of fuel at 20 m/s with varied cross-wind velocity at 3.77 m/s, 7.5 m/s and 10 m/s, and steam/fuel ratio at 0.14, 0.25 and 2.35.

Results and Discussion

The steam addition effect for various cross-wind conditions

In cross-wind 3. 77 m/s showed from the calculation result or combustion efficiency continued to decline with steam addition. A significant decline in combustion efficiency for S 2.35. It happened because of in cross-wind velocity 3.77 m/s cannot offset the number of steam in the flow of fuel where caused the imperfectly combustion and made the combustion efficiency leads and decrease.

Table 1 . The rate of species (10^5 kg/s) and the calculation result of the efficiency cross-wind velocity 3.77 m/s

Cross-wind Velocity (m/s)	S	$C_3H_{8\,in}$	$CO_{2\,out}$	η
3.77	0.14	9.8	9.7	99.3
	0.25	8.1	7.3	92.1
	2.35	3.7	1.2	34

Table 2 . The rate of species (10^5 kg/s) and the calculation result of the efficiency cross-wind velocity 7.5 m/s

Kecepatan Angin Silang (m/s)	S	$C_3H_{8\,in}$	$CO_{2\,out}$	η
7.5	0.14	5.9	5.8	98.3
	0.25	5.1	4.9	96
	2.35	2.1	0.4	0.19

The combustion efficiency in cross-wind velocity 7.5 m/s shown at table 2 above. Steam addition (S) until 0.25 can be done because not decrease the efficiency occurs but at S 2.35 intolerable because the smallness combustion efficiency result. However at cross-wind 10 m/s, the addition of steam strongly not effective given because the combustion efficiency obtained did not show the value of combustion efficiency which allowed for flare flame more than 95%. It is because of the fuel velocity given 20 m/s cannot offset the cross-wind velocity 10 m/s causing the imperfect combustion process.

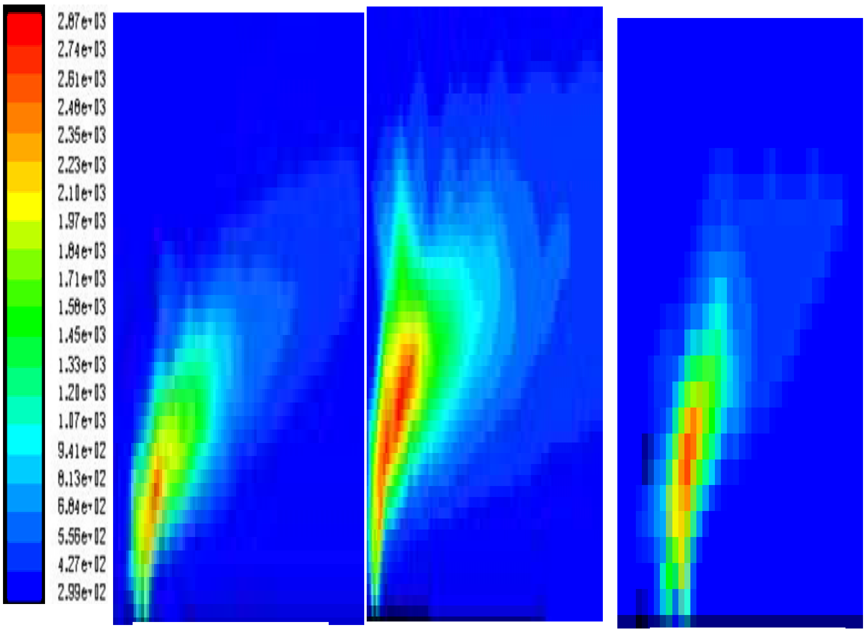
Table 3 . The rate of species (10^5 kg/s) and the calculation result of the efficiency cross-wind velocity 10 m/s

Kecepatan Angin Silang (m/s)	S	$C_3H_{8\,in}$	$CO_{2\,out}$	H
10	0.14	4.7	3.8	81.4
	0.25	3.8	1.9	31.7
	2.35	0.8	0.07	0.09

Cross-wind strongly influences the combustion efficiency, it shown from the calculation result of combustion efficiency. The higher of cross-wind velocity made combustion efficiency decrease. It's happened because the high cross-wind and some fuel not yet perfectly combustion but has blown by wind. It's also strongly influence by the amount of fuel given for counteract the influence of the cross-wind. However in this research, the velocity of fuel was constant 20 m/s. Meanwhile due to the addition of a steam in the flow of fuel (S) also influence the result of combustion produced. The increasing of value (S) seemingly made the decline of combustion efficiency, but the decline was significant happened in the cross-wind speed 10 m/s, in S 2.35, the combustion was imperfect and it can be identified by combustion efficiency value produce. It was the great addition of steam not recommended for the flare operation.

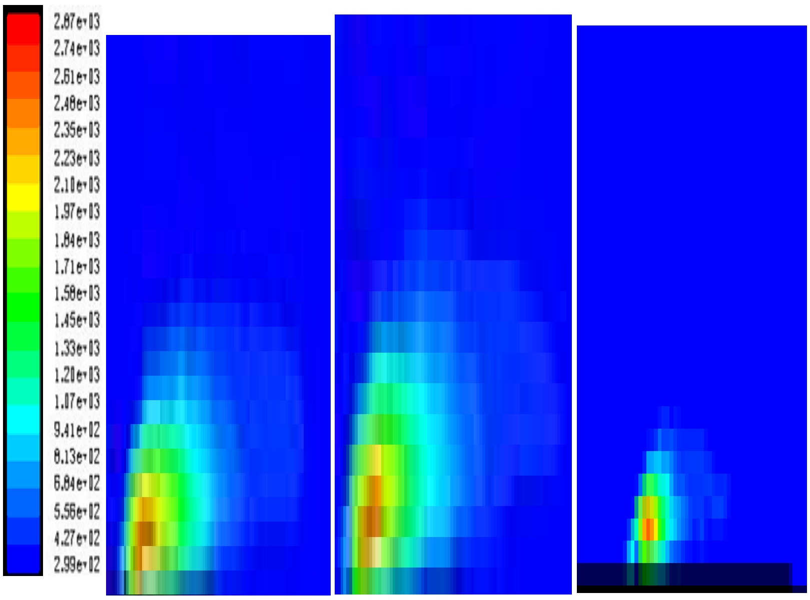
The temperature contour

Figure 2 show the temperature contours which produced in various velocity of cross-wind and various S value was given. The differences of contour picture colors show the differences temperature value which produce by each flame. From that contour show that the value of S which given in various wind velocity strongly influence to the combustion temperature produce, where the contours result can be known that the temperature of flame decreases the growing number of steam given in fuel flow, it showed in S value (2,35). In high S value can caused the extinguished flame most notably when a high cross-wind velocity and it shown from the temperature contour at cross-wind 10 m/s, it made the released of hydrocarbon compounds into atmosphere and allegedly also of smallness efficiency produce from it combustion burning process.



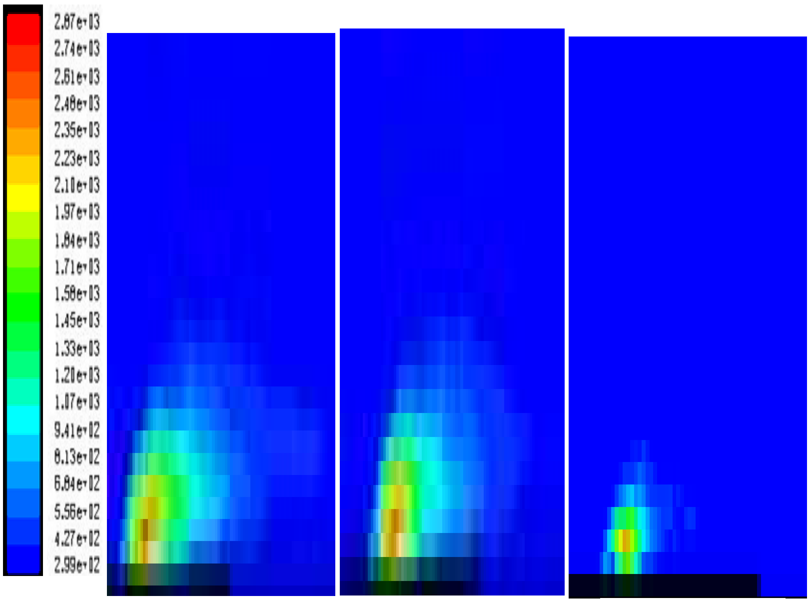
U_∞= 3,77 m/det S = 0,14 | U_∞= 3,77 m/det S = 0,25 | U_∞= 3,77 m/det S = 2,35

Figure 2. Temperature contours in cross-wind velocity 3, 77 m/s for various S value.



U_∞ = 7,5 m/det S = 0,25 | U_∞= 7,5 m/det S = 2,35 | U_∞= 10 m/det S = 0,14

Figure 3. Temperature contours for cross-wind 7,55 m/s for various S values.



U_∞= 10 m/det S = 0,14	U_∞= 10 m/det S = 0,25	U_∞= 10 m/det S = 2,35

Figure 4. Temperature contours for cross-wind 10 m/s for various S values

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