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Effect of baffles dimension on the combustion reaction inside an industrial sulphur burner

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Abstract

The sulphur boiler furnace used in phosphate industries usually contains three baffles. Their role is to guide the fluid flow inside the combustion chamber. So, they are useful to enhance a complete reaction. The present work shows a numerically investigation of the effect of increasing the baffles dimension on the combustion reaction that occurs inside a sulphur burner. The simulations are performed using the commercial software Ansys Fluent 16.2. A non-premixed combustion model is carried out. The fluid characteristics such as temperature, velocity and mixture fraction are presented.

Keywords: industrial, turbulence, combustion, baffles, simulation

1. Introduction

Nowadays, researchers focus their interest on the optimization of industrial applications. Their aim is to reduce the emissions produced by combustion processes. In fact, the incomplete combustion reaction inside burners can be very harmful for human health and for our environment. In this context, many previous studies used CFD simulations to study combustion processes [1-17]. The studied industrial sulphur burner is used in phosphate industries. Brown et al. [18-21] developed a similar process with one baffle and with six spray nozzles of molten sulphur. Their results are in good agreement with experimental results. They studies also the effect of spray nozzles orientation on the performance of the burner. Chidambaram [22] reported the thermal damage inside a combustion chamber with various evidences from visual inspections. Many repair solutions are proposed. This illustrates that CFD tools can improve knowledge about the internal reaction mechanism that occurs inside a fuel burner. It makes the optimization study more feasible. In our case, we evaluated the effect of baffles dimension on the combustion reaction inside a sulphur boiler furnace.

2. Numerical approach

The Ansys Fluent software is used to develop the numerical simulation of the fluid flow behavior inside the sulphur boilerfurnace. This equipment contains four air inlets encountering the four sulphur inlets and two secondary air inlets located on the top. The combustion chamber contains three baffles that guide the fluid until it will be evacuated by the outlet. A combustion reaction will occur between the injected liquid sulphur and the entered dry air. The burner geometry is presented in figure 1 and it is identical to an industrial equipment. The dimensions are detailed in a previous work.

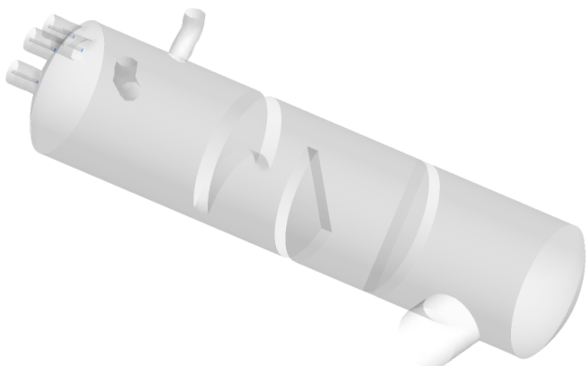


Fig 1.Sulphur boiler geometry

Figure 2 presents a mesh convergence study that is investigated in order to choose the adequate mesh. Different grid sizes are performed and reported. The elements size are 304 277, 582 473, 991 111 and 1 135 095. The fourth mesh is chosen in function of computations cost.

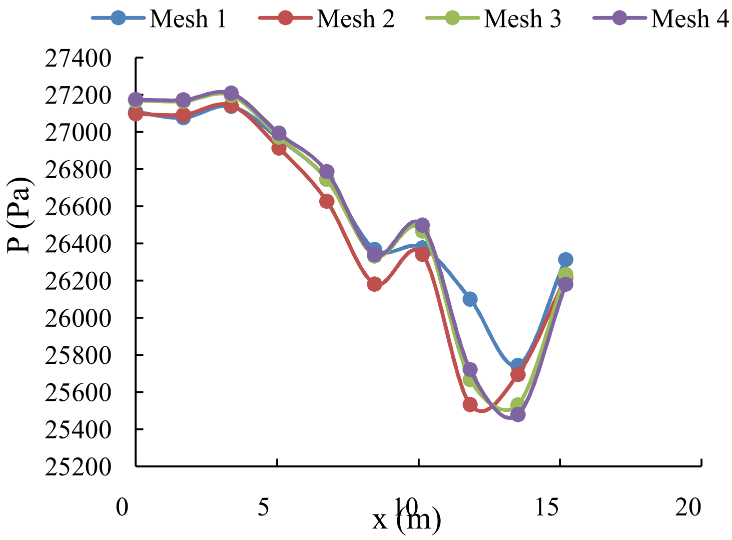


Fig 2. Mesh convergence

This is a non-premixed combustion model. It is very essential to choose the adequate combustion mechanism in the species model.In order to examine the numerical model validity, the numerical results are compared to data collected from the industrial. The data are measured in the outlet zone. A good agreement was shown.

For the baffles dimension modification, we present the following geometries as shown in figure 3. The width of the baffles is increased, the different parameters are presented in Table1.

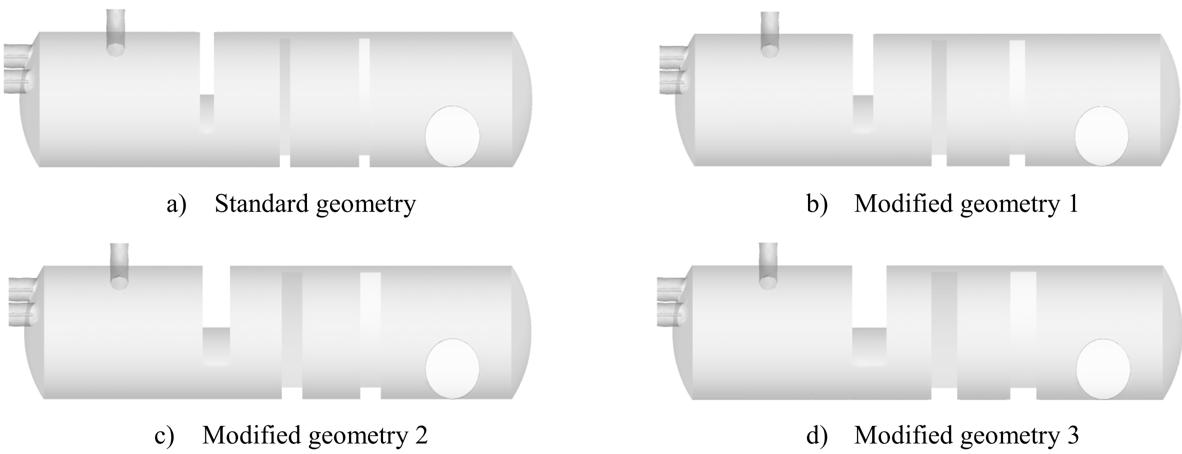


Fig 3. Geometry modifications

Table 1. Modified width dimensions

	Baffle width (mm)
Standard geometry	445
Modified geometry 1	667.5
Modified geometry 2	890
Modified geometry 3	1335

3. Results and Discussion

For numerical results we choose a reference plane in order to present the different distributions. It is located in the (xz) at z= -0.47m.

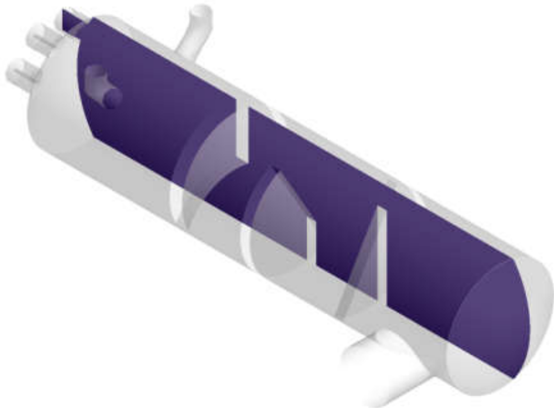
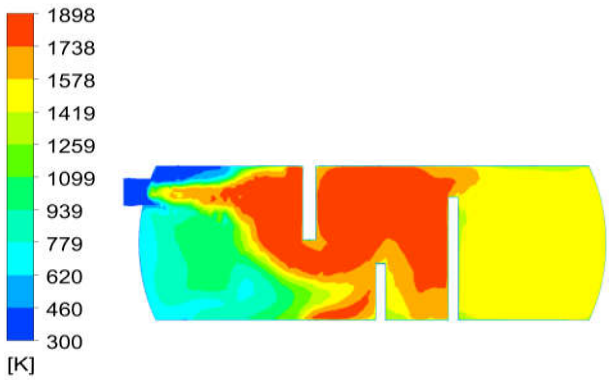


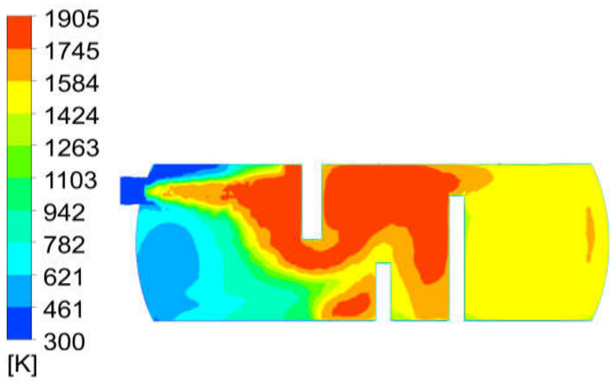
Fig 4. Reference plane

3.1. Temperature distribution

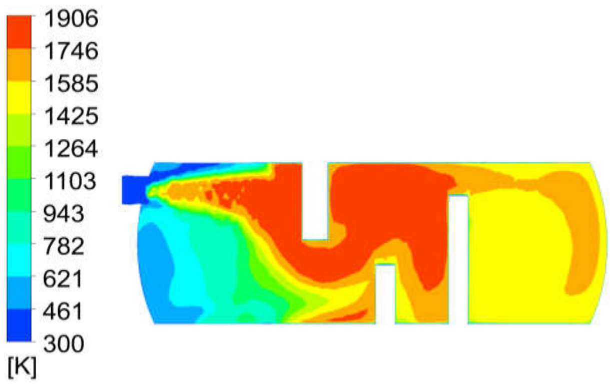
Figure 5 illustrates the 3D temperature distribution inside the modified sulfur boiler designs. It is observed that there is a vast red zone that presents the increase of temperature in the combustion chamber. In this area, the combustion reaction between the liquid sulphur and dry air occurs. It is very important to identify the fluid flow behavior then to optimize the design. In order to improve this industrial equipment productivity it is essential to have a complete combustion of sulphur. It is clear that the maximum temperature value is reached near the baffles zone. In fact, modifying the width of these baffles can affect the total reaction.



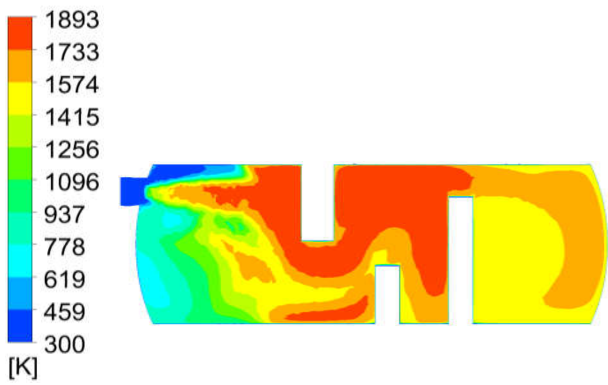
a) Standard geometry



b) Modified geometry 1



c) Modified geometry 2

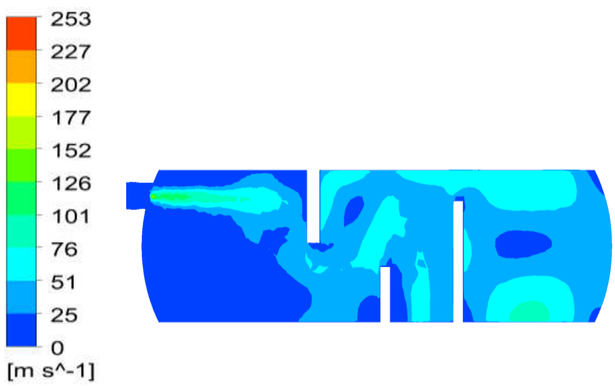


d) Modified geometry 3

Fig 5. Temperature distribution in 2D plane

3.2. Velocity distribution

Figure 6 presents the velocity magnitude distribution inside the modified sulfur boiler geometries. It is observed that the sulphur is injected with a high velocity compared to air velocity inlet. It is clear that the velocity distribution decrease when we increase the dimension of the baffles. In order to have a complete combustion, it is important to decrease the fluid flow velocity. So all the entered species should be well mixed. The velocity distribution could explain the fluid flow trajectories inside this burner.



a) Standard geometry

b) Modified geometry 1

c) Modified geometry 2

d) Modified geometry 3

Fig 6. Velocity distribution in 2D plane

3.3. Mixture fraction distribution

Figure 7 illustrates the mixture fraction distribution inside the modified sulfur boiler geometries in comparison with the standard geometry. It is obvious that the sulphur is injected in horizontal orientation. When the sulphur reaches the zone of the entered air, a combustion reaction takes place. This mixture produces the sulphur dioxide. So, in the baffles zone the sulphur disappears. It is seen that the mixture fraction appears with important value near the sulfur inlets.The numerical results show that the boiler design affects the mixture fraction distribution.

a) Standard geometry

b) Modified geometry 1

c) Modified geometry 2

d) Modified geometry 3

Fig 7. Mixture fraction distribution in 2D plane

4. Conclusion

In this paper, a numerical model focused on the non-premixed sulphurcombustion reaction was developed using the Ansys Fluent software. It was used to study the fluid flow inside an industrial sulfur boiler. We presented the modified geometriesin order to improve efficiency of the sulfur boiler. The modification of the boiler design was examined by means of CFD. The numerical simulation results revealed the fluid flow behavior inside these new designs. This study could be a useful tool to study the efficiency analysis and design optimization purpose.

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