Fluid simulation analysis of gas stove based on multi-jet cutting circle

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Abstract. This project aims to apply the principle of multi-jet cutting circle to transform the gas stove, improve the combustion efficiency of the gas stove, reduce the proportion of exhaust gas in the exhaust gas, and reduce the exhaust gas pollution of the gas stove. In this paper, Ansys software is used to conduct fluid simulation for gas stoves with different number of pipelines, and the influence of different number of ejector pipelines on combustion products, temperature and other results is obtained.

1. Introduction

After the introduction of natural gas into the market, atmospheric burners are widely used in gas appliances, and the consumption of natural gas increases rapidly. However, most gas stoves do not burn as efficiently as they should. Up to now, only about 10% of burner products in the market have reached the level 1 energy efficiency requirement (combustion efficiency ≥63%), while the proportion of burner products failing to meet the minimum level 3 energy efficiency threshold (combustion efficiency ≥55%) and facing obsolescence will exceed 15%.

This paper will start with the shortcomings of low combustion efficiency and high exhaust pollution of existing gas stoves, use the principle of multi-jet cutting circle, and use inventor software to conduct three-dimensional modeling of different number of pipelines of gas stoves, and finally use ANSYS software for fluid simulation to analyze the number of pipelines with the best combustion effect.

2. Principle of multi-jet cutting premix

The multi-jet tangential premix described in this paper is a premix that corresponds one to one between the guide jet tube and the gas nozzle, and has multiple ejector tubes sharing one head and communicating within the head. Different Numbers of venturi tubes were set up and the positions of venturi tubes were arranged reasonably to form a tangential mixed flow field. The ejector type atmospheric burner is formed by the suction of a certain amount of air by the kinetic energy of the gas from the nozzle through a different number of venturi tubes. By studying the influence of flow passage structure, premix chamber geometry, air and gas velocity and pressure on the air coefficient coefficient, as well as the study of the parameters of the atmospheric burner and repeated numerical simulation experiments, the reasonable premix chamber structure parameters are determined.
3. Structure design of multi-jet cutting premix

In order to realize the full premixed combustion, this work designs the air multi-path ejector, tangential circle mixing structure. Based on the idea of cutting round combustion of pulverized coal in large coal-fired boilers, different Numbers of venturi tubes are set up and the positions of venturi tubes are arranged reasonably to form a tangential mixed flow field.

Figure 1. Design model of three jet cutting premix.

After repeatedly adjusting the Angle of rotation about the Y axis of the venturi tube and the Angle of rotation about the Z axis (tilt up), the project team found that the Angle of rotation gradually increased until between 16° and 18°, the methane to air combustion coefficient was expected to reach =1.2. Beyond this Angle, the air coefficient gradually decreased, and the average velocity of ejecting air decreased. When the Angle of tilt is between 6.5° and 7°, the average velocity of ejector air reaches the maximum. Therefore, the work adopts the optimal working condition of =17° and =7° to conduct the combustion simulation of the multi-jet tangential premix.

Figure 2. The relationship between the rotating Angle meter and the air coefficient coefficient.
4. Premixed combustion analysis

Through the investigation and visit of the natural gas company, it was found that the flow rate of CH4 with natural gas line supplying the gas stove was about 2$m/s$, and the air entrapement speed was about 5$m/s$. Therefore, the above two conditions were used to set the parameters in this analysis, and the flow trace line and vortex center of methane premix combustion were obtained, as shown in the figure below.

4.1. Three - tube jet combustion analysis

The incoming airflow forms a good tangential circulation around the central axis and has a relatively stable vortex center, which is conducive to the rapid and stable mixing of methane and air. Due to the combustion of methane and air, the velocity of the outlet flow can reach 26.7633$m/s$.

The distribution diagram of temperature and product after combustion is as follows:
Figure 5. Combustion temperature, product distribution.

When the combustion temperature is high, NOX and CO2 are generated in large quantities, the temperature distribution in the combustion chamber is relatively uniform, and the premixing effect of CH4 and oxygen is relatively good. Combustion temperature of high value area and NO, CO2 spawning area appeared in the premixed implement conduit, favorable for combustion gas resides in tangential firing area and further mixing and combustion, basically eliminated the NOX rapidly due to the local rich fuel type, in addition, the monitoring of combustion area does not have the area of flame temperature higher than 1800 k, therefore generated when fewer type thermal NOX, NOX generation greatly reduced.
Figure 6. Combustion velocity, reactant distribution.

Methane is almost completely burned up after being mixed with oxygen in the premix pipeline. After the first half of the flow through the pipeline, the gas velocity is obviously stratified with the inlet velocity due to the expansion of combustion. Moreover, after entering the tangential premix region, the velocity field is evenly distributed, and the gas flow is stable, which is conducive to the stable emission of flame after combustion.

Export product: \( \text{CH}_4 = 1.86972 \times 10^{-8} \), \( \text{CO}_2 = 0.044715 \), \( \text{NO}_x = 2.93689 \times 10^{-14} \). The wall temperature is about 791.924K. The average outlet temperature is about 912.793K. The outlet pressure fluctuates between 110 and 190Pa.
4.2. Dual-tube jet combustion analysis

The tangential eddies formed by the incoming air flow around the central axis are also better, with a relatively stable vortex center, which is conducive to the rapid and stable mixing of methane and air. Also due to the combustion of methane and air, the outlet flow rate can reach 23.3752 m/s.

The temperature and product distribution after combustion are shown as follows:

![Combustion premixed flow trace.](image)

![Combustion temperature, product distribution.](image)

A large number of NOX and CO2 are generated when the combustion temperature is high. The temperature distribution in the combustion chamber is not even among the three tubes, and the temperature increases successively from inside to outside. Compared with the three tubes, the premixing effect of CH4 and oxygen is poor. The high combustion temperature region and the NO and CO2 generation region appear at the junction of premix pipeline and combustion furnace. Similarly, the monitored combustion area did not produce areas with the flame temperature higher than 1800K, so thermally generated NOX was also less, and the production of NOX was relatively low.
Figure 9. Combustion velocity, reactant distribution.

In premixed methane in the pipeline of the mixed with oxygen is almost completely burnt out after completely, after flowing through a pipe before two-thirds airflow velocity due to the effect of expansion of the combustion and inlet velocity appear obvious stratification, and the velocity distribution on entering the tangential premixed regional differences apparent, assumes the circular distribution, air flow is relatively stable, is conducive to the stability of the jet flame after.

4.3. Four-tube jet combustion analysis

Figure 10. Combustion premixed flow trace.
The incoming airflow forms a good tangential circulation around the central axis and has a relatively stable vortex center, which is conducive to the rapid and stable mixing of methane and air. Due to the combustion of methane and air, the air outlet velocity is up to 24.5614 m/s.

The temperature and product distribution after combustion are shown as follows:

**Figure 11.** Combustion temperature, product distribution.

A large number of NOX and CO2 are generated when the combustion temperature is high. The temperature distribution in the combustion chamber is relatively uniform, and a large number of them are distributed outside the combustion furnace. The premixing effect of CH4 and oxygen is relatively good. Combustion temperature of high value area and NO, CO2 spawning area appeared in the premixed implement conduit, favorable for combustion gas resides in tangential firing area and further mixing and combustion, basically eliminated the NOX rapidly due to the local rich fuel type, in addition, the monitoring of combustion area does not have the area of flame temperature higher than 1800 k, therefore generated when fewer type thermal NOX, NOX generation greatly reduced.

**Figure 12.** Combustion velocity, reactant distribution.
In premixed methane in the pipeline of the mixed with oxygen is almost completely burnt out after completely, after flowing through a pipe before 1/2 air velocity due to the effect of expansion of the combustion and the difference of inlet velocity is not very big, and in the tangential velocity distribution after premixed area is relatively uniform, air flow is stable, is conducive to the stability of the jet flame after.

5. interpretation of result
By facing the inventor modeling on ANSYS simulation results can be concluded that the two pipe jet exit of premixed speed 23.3752 m/s, three pipe jet premixed exit speed 26.7633 m/s, four pipe jet exit of premixed speed 24.5614 m/s, we can draw three tube jet exit velocity, the largest of premixed more maximize tangential jet velocity of premixed in premixed pipeline, how tangential combustion of premixed compared with the present stage of household kitchen burning gas effect is better. Also by ANSYS analysis can be concluded that the temperature of the cloud, highest, pipe jet exit temperature of premixed combustion effect best, the most suitable for the structure of kitchen burning gas, and then by the double pipe, three, four tubes cloud can be concluded that the product of analysis, three pipe jet of premixed combustion is the most sufficient, from the analysis of product also confirmed the above point of view.

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