The Control of Air Quality in Chinese Kitchen

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ABSTRACT

Chinese food is delicious. There are many kinds of cuisine. But the stir-fry, fry and deep-fry produce a large amount of steam and smoke which cause indoor air pollution seriously. So it must be controlled.

The paper gets some flow distribution regularity of steam and smoke current in Chinese cooking by testing in laboratory and advances a new method to prevent the diffusion of smoking current-kitchen hood with forced air screen. By comparing with other removers, the equipment can save heat (cold) load and improve indoor air condition greatly. The paper also analyzes blow and draw current of the equipment by fluid mechanics theories.

KEYWORDS: Cleaning Cooking Exhaust Kitchen Smoking

INTRODUCTION

Chinese cuisine has many cooking skills that make Chinese food welcomed in many countries. But most of these skills produce much more pollutants that are serious in large public kitchens, such as, in the hotels. Some of the exhaust materials can cause cancer. The polluted air not only harms the health of people, but also effects the quality of the kitchen and indoor air nearby. Of course, It will affects the hotel's business.

Now, an exhausted system comprised of a hood and a separated forced draught equipment alone is used popular in public kitchen in China. But the system is not much efficient in removing the smoking of edible oil and steam. Though the best way to improve is to increase the quantity of exhausted air (exhaust air volume) up to now, which the writers and many other experts studying and success years before. But the method has many problems also, such as, indoor cold (heat) load is increased and indoor pressure is lower than outside, because of a large amount of indoor air be exhausted, which making people feel uncomfortable. The energy consumption is more for increasing the volume of forced draught equipment, and the running fee is higher, and so on.

This paper gives an experimental formula of the smoking action and two kinds of blow and draw (absorb) equipment to show how to control the diffusion of exhaust air and how to reduce the volume of indoor air be exhausted.

METHOD

This is an experimental study (see figure 1 to figure3). A top of a kitchen range with 3 ovens is used. It is very popular in China by investigating statistics. It is 1400mm long, 800mm wide and 810mm high, The heating source is DZY-31A high heat load kitchen range. Each release heat load 8.7KW, and every radius is 350 mm. WBEK is semiconductor thermograph, and a pickup camera. QDF is a hot ball thermal anemometer. (These are omitted in figures).

For Chinese cooking skills, the stir-fry, fry and deep-fry produce more smoking,

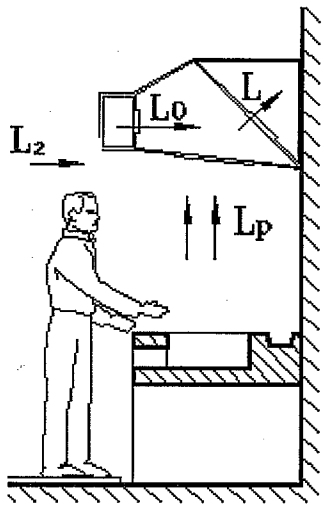

Figure 2 The blowing (jet) air system

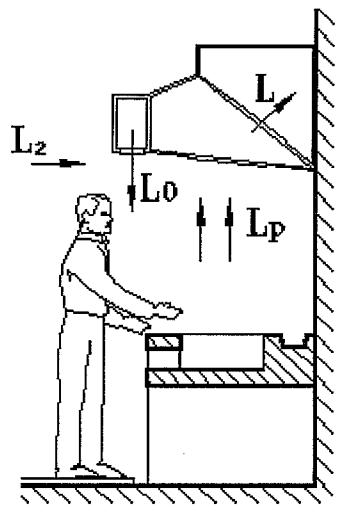

Figure 1 The forced air down system

especially stir-fry process. It abruptly produces a large amount of hot steam and oil smoking, every small amount of the smoking is hoped to be removed out (the largest exhausted smoking) to ensure the indoor air quality. But the smoking is unstable and changes its shape and amount from time to time, so the smoking is difficult to be controlled. On the basis of the experiment before [1], a hot water steam is used to instead of the smoking, because of its flow capacity and poverty and axle speed is same as the largest smoking.

The experiment makes use of a kind of blow and absorb (draw) hood. It comprises of two types. Each of them installs a still pressure tank in an ordinary hood. One is that the forced airstream vertically down and forming an air screen (see figure 1) The hood can exhaust the largest smoking, The volume of vertical airstream can be obtained by converting the air pressure. The other is that the forced airstream jet horizontally first (see figure 2), and then upwards slightly reaching the center of the hood. The forced air steam needn't pass through working area. So it can use fresh air directly, no need of treatment of heat (cold) or clearness.

The barometric instrument is Y-61 slope pressure meter and YJB-150 liquid compensation pressure meter and pitot tube。 The system sees figure 3.

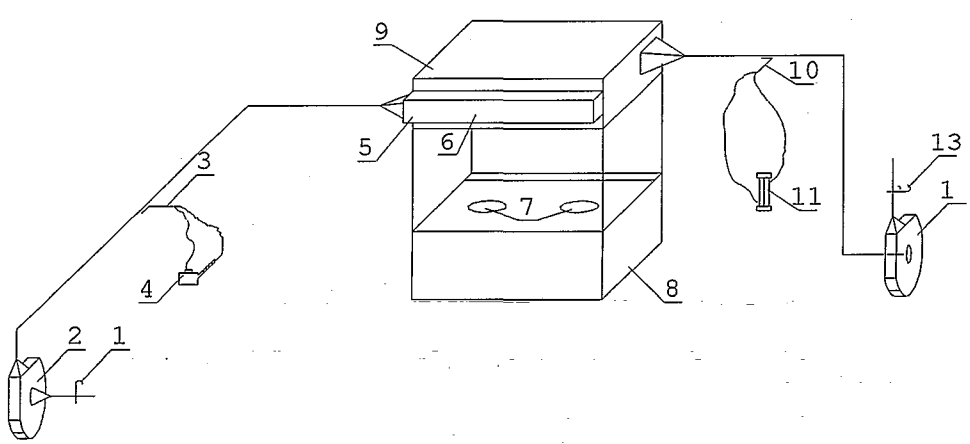

Figure 3 The experimental system

In this figure, 1, forced air regulating valve; 2, air blower; 3, pitot tube (forced air measurement); 4, slope micro-pressure meter; 5, stilling pressure tank; 6, crack air outlet,;7, top of the range; 8, the kitchen range; 9, exhaust hood; 10, pitot tube (exhaust air

measurement); 11, liquid compensation pressure meter; 12, exhaust air machine; 13, exhaust regulating value. The distance between the lowest level and the top of the kitchen range is changed from 1.1~1.3 meter.

Two factors K_L and η are introduced to evaluate the effect of air screen hood (figure 1). The K_L means limit volume rate, the η means the hood efficiency. When an ordinary hood works, the hood will absorb the smoking volume L_P and some kitchen's indoor air L_2 (invalid air) as well. The hood's whole exhaust volume L will be as follows:

$$L = L_P + L_2 \qquad (1)$$

When an air screen hood works, the forced airstream quantity is L_O. The exhaust volume L will be:

$$L = L_O + L_P + L_2 \qquad (2)$$

If there is no smoking leaked, K_L and η can be calculated by following equations.

$$K_L = \frac{L_2}{L_P} \quad \text{(ordinary)} \qquad (3)$$

$$K_L = \frac{L_2 + L_P}{L_O} \quad \text{(airscreen)} \qquad (4)$$

$$\eta = \frac{L_P}{L} \qquad (5)$$

The smaller K_L is, the less the invalid indoor air is, and the better the hood exhausts. When η equals 100%, it means that the exhausted smoking is all oil smoking and steam, while the exhausted invalid air is zero.

Figure 4 is model of air current in figure 2. The current of blowing air (jet air) makes up a movement in hood air. Three airstreams are complex. There is 15 degrees between main (real) air current direction and blowing air' s. On the basis of principle of a type of blow and absorb (draw) exhaust system [2], it is given:

$$\frac{V_P}{V_X} = tg\alpha \qquad (6)$$

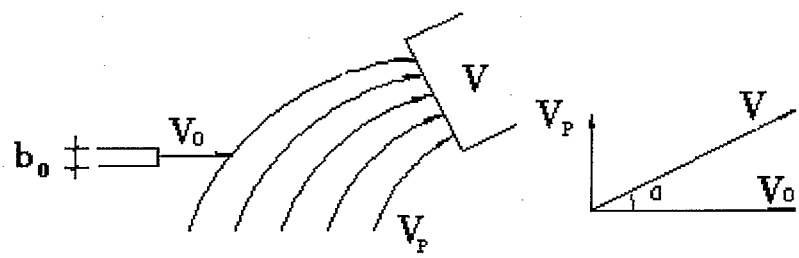

Figure 4 The model of blowing air current.

Where V_P is the average speed of the entrance of smoking (m/s); V_m is the controlled average speed of the blowing air (the end average speed of jet air in hood) (m/s); α is the angle of the controlled speed direction and the real absorbing speed direction.

Because of the limited width of a hood, the distance between the blowing airstream vent and the absorbed vent is narrow .The blowing airstream is in the beginning phase of jet before reaching the absorbed vent. The jet air also has adherence property towards top of the hood.

So three formulas are given to calculate the beginning average speed and volume of the blowing airstream and the end average speed and volume of the absorbed air [1]. Then the exhaust effect of figure 2 will be attained.

$$\frac{V_x}{V_O} = \frac{1 + 0.43 \, as / b_o}{1 + 2.44 \, as / b_o} \qquad (7)$$

$$\frac{L'}{L_0} = 1 + 0.43 \frac{as}{b_o} \qquad (8)$$

$$L_o = 3600 b_o I V_O \qquad (9)$$

Where V_x the end average speed of jet air (m/s); V_O The average speed of jet air volume (m/s) b_o the high of blowing air vent, a the turbulent coefficient of the blowing air vent; I the length of air vent (mm).

RESULT

Below are the main findings from the research.

1. The smoking current

Figure 5 shows the steam current distribution. The current speed is increased from below to above. The regulation of the smoking is similar to the convention jet air. According to measurement and statistic analysis, the volume of the smoking section of Chinese cooking is:

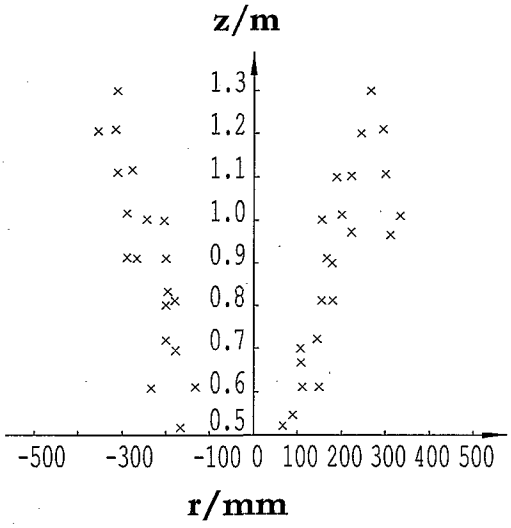

Figure 5 The distribution of steam

$$L_p = 57.854 Q Z^{1.649} \qquad (10)$$

Where Q the heat load of the kitchen range (Kw), Z the distance between the top of the kitchen range and the smoking section (m).

When changing the high between top of the range and smoking entrance from 1.1m to 1.3m, The factors of smoking will change soon such as speed and volume (see table1).

Table 1. The main factors of smoking

Z	V_P	V_M	L_P	D_P
1.1	0.46	0.95	528	650
1.2	0.49	0.98	633	670
1.3	0.51	1.06	695	710

Where Z the distance between the top of the range and the smoking entrance (m); V_P the average speed of the smoking (m/s); V_M the center speed of the smoking (m/s); L_P the sectional volume of the smoking (m/s), D_p the average radius of the smoking (mm).

2. Exhaust effect of blow and absorb hood

Table 2 shows the property of hood with air screen.

Table 2 Average poverty comparison

Type of hood	K_L	η(%)	V_P(m/s)	L_O/L (%)
Ordinary	0.340	76.7	0.324	
Air screen	0.143	87.5	0.308	12.4

Condition: L_O =260~412 m^3/h, L_P =734~1449m^3/h, L = 1760~2805 m^3/h.

Table 3 shows the property of hood with blowing air horizontal.

Table 3 Main factors of blowing air hood

z	V_X	V_O	L_O	L'	L	L_P	L_O/L (%)	η(%)
1.1	1.72	3.96	998	1386	1661	528	60	31.78
1.2	1.83	4.22	1063	1474	1769	633	60	35.78
1.3	1.90	4.37	1101	1527	1833	685	60	37.92

In this case, the L is whole exhaust volume (m^3/h) the condition factors: $b_o = 100mm, L = 700mm, S = 750mm, a = 0.12$.

DISCUSSION

From the table1 and figure 5, it is found that the smoking current can be divided into three stages: beginning, compression and diffusion. A hood is often installed in diffusion stage (the lowest level is about 1.1 meter above the top of a range). From the equation (10), we can find that it is important to control the smoking stage of diffusion and change the position (high) of a hood. The smoking poverty and datum can be used as a regulation to design and appraise the hoods of public kitchens.

From the table 2, It is found that the exhaust effect of blowing and absorbing hood with forced air vertical screen is higher than an ordinary one. This is because the forced down air can make an air screen that reducing the absorbed region of a hood. So the exhaust system raises the speed of the hood, and cuts down the exhaust volume, and then reduces the first investment and the running fee.

The very important is the forced down airstream need not treatment of clearness and heat (or cold). This can cut down heat (cold) load more and size of the exhaust system. So the system can save more energy than ordinary ones. It also improves the kitchen's air quality and makes exhausted indoor air less and makes cookers (people) feel comfortable.

There are about 60 percent of jet air volume in exhaust volume. The center speed of jet air is much higher than the edge. The distribution regulation of jet air just matches the smoking, so the jet air carry the smoking well. It makes the exhaust well for jet (blow) air to induce the smoking absorbed into the hood (figure 5). It also prevents the smoking diffusion for the blowing air forming upside current in hood entrance. From table 3, the volume of blow air adds volume of the smoking is equal to (or a little less than) the exhaust volume. It means the invalid air (absorbed indoor air) volume is exhausted very little in this exhaust system (or hood) of public kitchen. This will be better for equilibrium of indoor air and for reducing the minus pressure that lending to difficult breathing. It also has the advantages of saving energy, costing less, and stopping diffusion as figure 1.

It is also found (table 3) the exhaust efficiency of the hood is lower. This is because the carrying function of the jet air that must have some momentum (high speed) to induce smoking and the whole volume of the jet air must be exhausted. So the exhaust volume is more. It must be concerned in designing exhaust system about how to improve the hood factors to overcome the shortcoming (It is studied now).

In a word, The blow and absorb hood controls diffusion well, improves the quality of kitchen air, saves energy and costs little. It will be of a good prospect.

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REFRENCE

[1] Duanmu Lin, etc, Jun 1996. Poverty and Appraisal of the Hood of Public Kitchen. Journal of Shenyang Architectural and Civil Engineering Institute.

[2] Shun Yijian, 1994. Industrial Ventilation. Chinese Architectural Industry Publishing House .

[3] Wei Runbo, 1981 .Air Current Theory of Ventilation . Chinese Architectural Industry Publishing House.

[4] Zhou Moren, 1983. Fluid Mechanics Theory. Chinese Architectural Industry Publishing House.