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Study on double ignition characteristics of gasoline engine

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Abstract. According to the treatment benchmark of the combustion model of gasoline engine, a limited planar approximation method is created to calculate the combustion model with Monte Carlo Principle. The combustion conditions of the single and double spark plug ignition in phase are calculated with the method. It can be found that double ignition burn faster than single ignition, and the combustion has good performance when double spark plugs are arranged the Central position of the combustion chamber.

Key words. Monte Carlo principle, combustion model, double ignition.

1. Introduction

Due to the deep research on the combustion process of gasoline engine and the progress of computer technology, the development and application of gasoline engine combustion model have been developed rapidly. The application of quasi-dimensional combustion model is remarkable, and the area of flame front surface can be calculated and analyzed. Including the interference of the flame and the combustion chamber wall [1], [2]. In the previous calculation model, the plane model is usually used to solve the combustion model by plane nodal integration method or spherical triangle method. Because of the different methods of different combustion chambers, different integral regions will be generated, which will lead to the calculation of the workload, Difficulty, calculation results and calculation accuracy is not consistent, not easy to comprehensive comparison. Therefore, the finite plane approximation method is used to optimize and the finite combustion method is used to analyze the different combustion conditions of the double spark plugs, and the quick burning characteristics of the double spark plug are verified [3]-[6].

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2. To establish the combustion equation of double spark plugs

(1) To establish a finite plane approximation method, that is, first with a limited number of planes to approach the combustion chamber, and then use the Monte Carlo method of combustion chamber burned area volume and flame area calculation[5], [6].

(2) Burning calculation of double spark plugs

The three-dimensional Cartesian coordinate system is established by using the center of the bottom of the hemispherical combustion chamber as the origin of the coordinates.

The wall equation of the hemispherical combustion chamber: $x^2 + y^2 + z^2 = R^2$

The position of the spark plug 1 is(x_1, y_1, z_1),the position of the spark plug 2 is(x_2, y_2, z_2), such that the flame burning speed is v, so at time the flame front area is the sum of the following two regions.

Area 1: All points satisfy the following equations:

$$(x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 = (vt)^2 \tag{1}$$

$$x^2 + y^2 + z^2 \le R^2 \tag{2}$$

$$(x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2 \ge (vt)^2 \tag{3}$$

Area 2??All points satisfy the following equations:

$$(x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2 = (vt)^2 \tag{4}$$

$$x^2 + y^2 + z^2 \le R^2 \tag{5}$$

$$(x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 \ge (vt)^2 \tag{6}$$

The area of the burned area is in the following two areas:

Area 1: All points satisfy the following equation:

$$(x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 \le (vt)^2 \tag{7}$$

And these points also satisfy the equation (3) and the equation (4) simultaneously.

Area 2: All points satisfy the following equations:

$$(x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2 \le (vt)^2 \tag{8}$$

And these points also satisfy the equation (3) and the equation (7) simultaneously.

a. Calculation of the volume of burned area

N uniformly distributed random points are produced with the Monte Carlo method in the combustion chamber. At the same time the sum of points in the burned area is calculated in “n” points and it is marked as “ k ” . Then the volume of the burned area is shown as follows:

$$V = \frac{4\pi\left(vt\right)^3}{6} \times \frac{k}{n} \tag{9}$$

b. Calculation of the flame front area

N uniformly distributed random points are produced with the Monte Carlo method on the sphere of the equation (2). Then the points in “n” points are calculated to satisfy the equation (3) and the equation (4). The sum of the points is marked as “$\left(x - x_2\right)^2 + \left(y - y_2\right)^2 + \left(z - z_2\right)^2 = \left(vt\right)^2$”.

N uniformly distributed random points are produced with the Monte Carlo method on the sphere of the equation (5). Then the points in “n” points are calculated to satisfy the equation (3) and the equation (7). The sum of the points is marked as “k_2”.

Then the flame front area:

$$S = \frac{k_1 + k_2}{n} \times 4\pi\left(vt\right)^2 \tag{10}$$

3. Analysis of ignition and combustion of double spark plugs in different condition

Take a 125ml hemispherical combustion chamber as an example, make the following settings:

The radius of the hemispherical combustion chamber is 28mm, the velocity of the flame in the combustion chamber is set at 40m/s, the coordinate system is established at the center of the hemispherical horizontal plane.

(1) Comparison of the situation one

(0. 0, 14), in units of mm, double spark plugs, the coordinates of the two spark plugs are (-14, 0, 14), (14, 0, 14), the unit mm The Using Matlab Tool to prepare the calculation program, the calculation results shown in Figure 4.8.

From the left side of Figure. 1, we can see that the flame front area formed by the ignition of double spark plugs is larger than the flame front area formed by the ignition of single spark plug, because this stage belongs to the obvious burning period, and the flame has not been transmitted to the cylinder wall , The two fire cores formed two fireball surface area than a fireball surface area. In 0.00038 seconds, the two cases of the flame front area are close to the maximum, but the flame front area of double spark plugs is larger than that of single spark plug. In the 0.00042 seconds, the flame front area of single spark plug is larger than that of double spark plugs, because the flame surfaces of double spark plugs are intersected, the flame front area is reduced. In 0.0008 seconds, all the flames reach the entire combustion chamber at the same time.

It can be seen from the right side of Figure. 1: In the range of $0 \sim 0.0005$ seconds, the combustion volume of double ignition is 2 times of the combustion

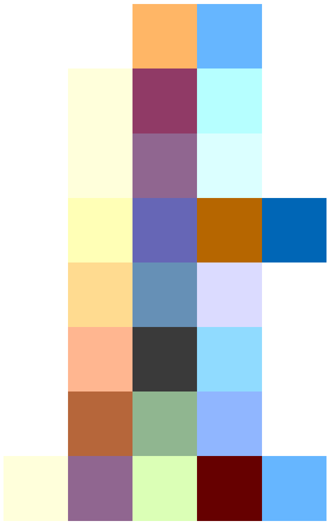

Fig. 1. Comparison between one spark in center and two sparks located at two sides

volume of single ignition. When the time exceeds 0.0005 seconds, the two flame surfaces of double spark plugs are intersected, the combustion volume is no 2 times of the combustion volume of single spark plug. All the flame surface reach the whole combustion chamber in about 0.0008 seconds, and the frontal area The calculation is consistent. In general, in the range of from 0 to 0.0008 seconds, the combustion volume of double ignition is greater than the combustion volume single ignition.

(2) contrast case two

(2, 8, 18.7), in mm, double spark plug condition: two spark plugs are arranged symmetrically with coordinates (-18.7, 0, 18.7), (18.7, 0, 18.7), in mm. Using Matlab Tool to prepare the calculation program, the calculation results shown in Figure 4.9:

From the left of Figure. 2 it can be seen that the flame front area formed by the double ignition is close to the flame front area formed by single ignition in the range of $0 \sim 0.00028$ seconds. In the period of $0.0028 \sim 0.00056$ seconds, The flame front area formed by the double ignition is larger than the flame front area formed by the single ignition. In the period of $0.00056 \sim 0.0008$ seconds, the flame fires of single

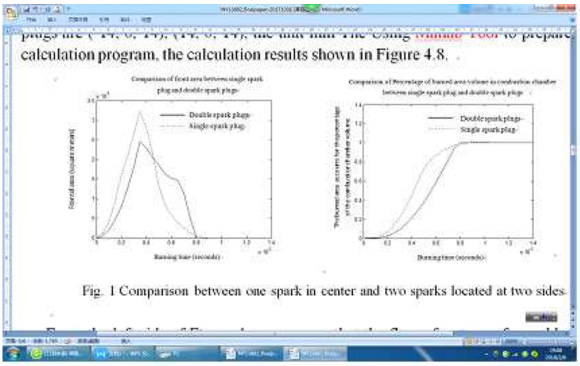

Fig. 2. Comparison between one spark at one side and two sparks located at two sides

ignition are larger than the flame fires formed by double ignition. All the flames reach the entire combustion chamber in around 0.0009 seconds.

From the right of Figure. 2, we can see that the combustion volume of double ignition is 2 times of the volume of single ignition in the range of 0 $\sim$ 0.0005 seconds. When it is more than 0.0005 seconds, two fireballs formed by double ignition will intersect. It's burning volume is no longer 2 times of the volume of single ignition. All the flame surface will reach the entire combustion chamber in 0.0008 seconds or so, which is the same with the frontal area calculation.

(3) contrast case three

Assume that two sets of double spark plugs are symmetrical. (14, 0, 14), unit mm, double spark plugs condition 2, two spark plugs coordinates were (-18.7, 0, respectively) 18.7), (18.7, 0, 18.7) in mm. Using Matlab Tool to prepare the calculation program, the results shown in Figure 4.10:

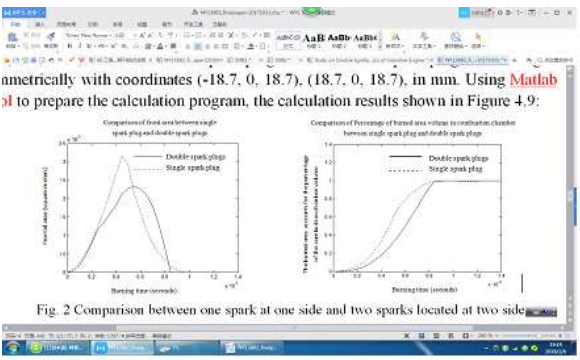

Fig. 3. Comparison between different two-sparks located in different positions

From the left side of Figure. 3 we can see that in the range of 0 $\sim$ 0.00038 seconds, the flame front area of working condition I is larger than that of working condition II. The two spark plugs of the working condition I are evenly distributed in the middle of the combustion chamber, and the two spark plugs of the working condition II are relatively close to the combustion chamber wall. Therefore, the flame propagation distance of the working condition I is short and can reach the whole combustion chamber in 0.0008 seconds, and fire burning flame surface of the working condition II can reach the entire combustion chamber in 0.0009 seconds or so.

As can be seen from the right side of Figure. 3, the combustion volume is the same as the size of the fireball formed by the ignition of the spark plug on two different conditions at the beginning of the combustion. As the combustion continues, the flame near the combustion chamber wall and combustion volume of the working condition II is relatively smaller than the working condition I. In the range of 0.0008 seconds, the flame surface of the working condition I reaches the entire combustion chamber. the flame surface of the working condition II reaches he entire combustion chamber in around 0.0009 seconds, which is consistent with the frontal area calculation.

In summary, double ignition burn faster than single ignition, and the combustion has good performance when double spark plugs are arranged the central position of the combustion chamber.

4. Conclusion

Based on the Monte Carlo Principle, a finite plane approximation method was used to calculate the combustion model and the finite element method was used to calculate the combustion process of different ignition modes. It can be found that double ignition burn faster than single ignition, and the combustion has good performance when double spark plugs are arranged the central position of the combustion chamber.

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