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Study on combustion properties of magnesium-rich propellant based on analysis of kneading mixture

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Abstract: In order to improve the combustion performance of the magnesium fuel, the heat value and combustion temperature of the mixture and the propellant were analyzed. The results show that: At the kneading machine speed of 1600 r/min, the magnesium and aluminum-rich fuel was prepared by adding propellant, with a calorific value of 2420 kg / t. The propellant has high calorific value, low combustion temperature, low non-combustible content, no by-products of combustion products, and low environmental pollution. Rich fuel shall meet the following requirements in use: First of all, the rich fuel should be added to the rich fuel to meet the combustion performance requirements; Secondly, to ensure that the mixing effect of rich fuel and mixture is consistent; Again, to ensure that the rich fuel does not produce harmful gases at higher temperatures. Rich fuels contain a variety of metal elements and trace elements (P / K), and their chemical composition is also different from traditional fuels such as coal and oil. According to the working principle and characteristics of the kneading machine, the type and added amount of rich fuel can be reasonably selected; At the same time, it can also consider the use of different metal elements and trace elements with different mixing amounts and different fuel composition, and reasonably choose the type and added amount of rich fuel.

Keywords: Fading machine mixture; Magnesium and aluminum are rich in fuel propellant; Combustibility.

1. Foreword

In the new century, both the West and Russia attach great importance to tactical missiles, and the functions and functions of "non-contact" out-of-sight operations and high-speed supersonic maneuver and remote strike operations in the vast sky are becoming more and more prominent. General solid rocket engines and turbojet engines are difficult to reach the required level of such missiles in terms of performance, size, quality and other aspects, but their thrust is 3-5 times larger than rocket engines, and small size, simple structure, especially suitable for supersonic navigation, therefore, after decades of development, the development technology of solid rocket stamping engine has attracted the attention of the world again, and will be widely used after the 1990s, and a new generation of high-performance solid rocket stamping engine is expected to start in service in the beginning of this century. The solid rocket stamping engine consists of a gas generator (primary combustion chamber) and an auxiliary combustion chamber (secondary combustion chamber), in which the fuel-rich propellant combustion is stable and the injection efficiency is high. The combustion speed requirements of various types of rocket engines improve with the improvement of the weapon performance requirements, and the combustion speed is the key factor to evaluate the engine performance. The powder combustion speed is an important parameter affecting the energy representation number of the propellant and the main factor affecting its performance. Standard material is a sufficiently uniform and determined characteristic value used to measure the measurement device, evaluation or assign value to the material, with high consistency, better stability and more accurate measurement value. As with other measurements, the basic role of gunpowder combustion velocity standard matter is reproduction, preservation, and transmission to ensure comparability and consistency between different temporal and spatial scales, underlying the measurement of gunpowder combustion velocity. In order to meet the requirements of fixed value of low speed standard, transmission of quantity value and calibration of speed test equipment, the author adopts a suitable combustion speed catalyst to ensure the quality of the liquid, ensure the combustion speed, and ensure the quality of the combustion speed.

2. Overview of magnesium-rich propellant

The research of high solid fuel started late, but developed rapidly, especially in industrial fuel. At present, industrial fuels mainly include coal, oil, gas, liquid helium and so on. Because of the small volume density of these fuels is large, significant, insufficient combustion, did not play a large range of combustion effect, so the combustion performance is relatively poor, fuel combustion produces a large number of carbon monoxide, nitrogen oxides and other harmful gases have a certain pollution to the environment. At present, the world mainly produces high solid content (H2O) and low temperature propellant combustion. The propellant mainly consists of alumina, magnesia, coal, coal gangue, fly ash, coal tar, etc. Among them, magnesium hydroxide and aluminum powder are the main combustion raw materials in the traditional fuel industry, which have the advantages of fast combustion speed, short reaction time, no oxygen consumption, high combustion point, and no waste gas production. But the combustion process can form a large number of harmful substances and a large number of waste residue, causing certain harm to the environment. Therefore, people began to study the propellant combustion performance and pollutant emission changes. With the development trend of environmental protection and low carbon is also getting more and more attention, the current application scope has been very wide. At present, there are many problems such as

low combustion efficiency, low combustion temperature and volatile. Therefore, it is particularly important to develop the new combustion technology. This test used RF-TEP to analyze the decomposition and dispersion of the homogeneous mixture to characterize the particle size and particle size distribution of low melting point matter during combustion, and to conduct combustion performance analysis. The results show that using two-speed mixing equipment and equalization system of high speed and high shear mixture. Performance of common fuels as shown in Table 1,Can meet the environmental protection requirements.

Table 1. Common fuel performance comparison table

class	calorific value, MJ/kg	density, g/cm3	Volume heat value, MJ/L
Ti	15.8	4.51	71.4
Zr	12.0	6.52	78.2
Mg	24.8	1.74	43.1
Al	31.1	2.70	83.8
B	58.0	2.34	135.7
fluorene	40.2	1.20	48.2
anthraquinone	31.4	1.44	45.2
cubane	46.4	1.29	59.9
carborane	58~67.6	0.9~1.0	53~67.6

3. Experimental process analysis

The test raw materials were MgO2 powder and aluminum silicate powder. MgO2 powder belongs to Al2O3 non-combustible solid, its poor combustion characteristics, combustion produces a large number of black smokes, is not conducive to the environment and human health. Aluminum silicate powder belongs to the acid solid, often used as a combustion supporting agent in the refractory industry; MgO2 powder belongs to the alkaline solid, is a combustible solid substance, its combustion performance is good. During the experiment, the above two resources were mixed in a ratio of 2:1:3 and ground evenly. After grinding, propellant was added to grind the mixture and make it fully mixed evenly with aluminum silicate powder for combustion test. The raw materials used for the experiment were placed in an airborne beaker in the laboratory, and then 100 mL of copper sulfate solution (pH 5) and 10% silver nitrate solution (pH 7) were insulated for 2 h at 200~250℃, then removed and put into a cooling plate and dried in the powder mixture. Mix the powder and aluminum silicate powder at 2:1:3 and 1:3 and 2:1:3 in the mixer, and be ground and polished. The resulting mixture was dried at 400 to 500℃ for 3 h to produce a powdered mixture. Heat the mixture in a beaker with air and stir until the reaction is uniform. Then put the stirred concrete and beaker into the well mixer for high-speed mixing, the time is more than 2 h, and then take out and put into the cooling dish to cool it to room temperature, and put into the oven for baking for about 3 conduct the drying procedure after the mixture becomes fully melted. Physical and chemical properties of the test fuels are shown in Table 2:

The Tesla FF50-6 fuel consumption tester (test) measured that the average fuel consumption of magnesium and aluminum-rich fuel propellant was 13.075 kg/min, which was higher than the FF50-6 fuel consumption. In order to understand the combustion characteristics of magnesium and aluminum fuel-rich propellant under different conditions, the comprehensive evaluation test is conducted according to the above data: The prepared magnesium and aluminum-rich fuel propellant was placed at 200~250℃ for 2 h, and then removed and put into the cooling dish to dry it, to get the powder mixture; The dried powder mixture was placed in 10 mL copper sulfate solution (pH 5) and 10% silver nitrate solution (pH 7) for 1 h, and the propellant was burned under different conditions at a combustion temperature of 233℃[3].When the heating temperature is higher than 233℃, more oxides will be formed on the surface of magnesium aluminum fuel-rich propellant particles, reducing the heating temperature, and reducing the diffusion coefficient of magnesium aluminum fuel-rich propellant, thus reducing its combustion performance at high temperature.

Table 2 Physical and chemical properties of fuel

fuel	Polymethoxydimethyl ether (PODE)	carbinol
oxygen content /%	48	49.9
cetane ratio	76	3
density (20℃)/kg·m-3	1.05	0.796
low heating value/MJ·kg-	17.8	19.66
latent heat of vaporization (KJ/kg)	300~450	464
viscosity	1.9	0.59

During the process of combustion product analysis, the mixture and propellant combustion products were observed by scanning electron microscope (SEM), while the gas composition analysis (CO, H2O, NOx) was conducted by GC-MS, and the thermal decomposition products of the combustion products were analyzed by X-ray diffraction analysis (XRD).The results show that: At 400℃, the CO, H2O, and NOx in the molten state show different diffusion speeds along with the different combustion products; At 400℃, the melting state and the particle state are well dispersed, and the melting product is almost no melting state, indicating that the propellant fuel has a good ant ignition point (the decomposition begins at 250℃);When 200 mL of copper sulfate solution (pH is 5) is added, the reaction peak is significantly narrowed, which indicates that MgO2 powder is an excellent combustion-supporting raw material; At 400℃, it reacts with NaOH when melting, and it first decomposes at 700℃;When the 100 mL silver nitrate solution (pH is 7) is added, the reaction will be completely stopped, and the combustion

product is white and a large amount of white smoke is produced; When 200 mL of copper sulfate solution (pH = 5) was added, the reaction was stopped completely, and then ashes and other substances were generated. Above 600℃, the fastest reaction speed can be maintained for 3 min, and the longest reaction time can be over 10 min when the reaction temperature reaches over 900℃.

The combustion products of magnesium and aluminum-rich fuels can be divided into three categories, including nitrogen oxides, carbon monoxide, and sulfur dioxide (CO). A 2 D flame centrifuge is used to generate heat from the flame center in contact with the gas. The temperature of the combustion gas is used to determine the content of volatile substances and carbon monoxide in the gas. The volatile gas of the organic matter in the combustion material can also be measured by the combustion gas pressure measurement method. The concentration was determined by GB / T 14347-2000.

4. Interpretation

The amount of propellant increases with the increase of coal fly ash, but the coal consumption decreases, the combustion performance is more stable, no black smoke. The main reason is that pulverized coal contains sulfide and sulfur oxide is a colorless and tasteless gas, the pollution to the surrounding atmosphere is very small, in addition to the combustion process can release a large amount of oxygen, is conducive to the fuel in the whole process of full redox reaction, therefore, adding an appropriate amount of pulverized coal has a certain promoting effect on the decrease of coal consumption. The high coal consumption and poor combustion performance in propellant fuel cannot fully achieve the purpose of environmental protection requirements and economic efficiency. Adding the right amount of pulverized coal can effectively improve the combustion performance of propellant and improve the environmental protection performance of propellant.

4.1. Coal fly ash

Coal fly ash is a kind of powder with high carbon content and more impurities, the main components are calcium carbonate, magnesium aluminum, etc., among which the content of lime is higher, and the mass fraction of fly ash generally accounts for 60%~70%.Coal fly ash forms activated carbon at high temperature and oxidizes into hydrogen, oxygen, nitrogen and other gas molecules, reducing the risk of black smoke and air pollution generated by fuel combustion. Coal fly ash contains a certain amount of calcium carbonate, at high temperature can form insoluble calcium carbonate and calcium oxide and other substances, reduce the ash content in pulverized ash, promote coal fly coal; The moisture content of coal fly ash is high, which increases the specific surface area of pulverized coal, improves the dissolution and flow of pulverized coal melting process, thus reducing the risk of coal smoke and black smoke in the production process of thermal power plants, in addition, pulverized coal also contains a lot of oxygen, hydrogen, nitrogen and so on. The experimental results show that, compared with pulverized coal, pulverized coal can form a good mixture ratio when mixing evenly with cement, lime, metal and fiber, which can not only reduce its mass fraction, but also promote the propellant combustion and improve the propellant incineration performance.

4.2. Mix and material analysis

The main component of the mixture is magnesium aluminum rich fuel coal fly ash, lignite. The highest content of coal fly ash, 34%, and the lowest content of fly ash, 16%, and coal ash to some extent changed the coal powder in combustion particles, affect the precombustion of magnesium aluminum rich fuel, and coal, coal ash, lignite to a certain extent, promote the coal consumption of propellant and propellant environmental performance. In addition, it is found that the higher the content of coal fly ash, the more sensitive to the change of pulverized coal combustion performance is not conducive to energy conservation and emission reduction and safe production, so reasonable control of coal fly ash content can effectively reduce the impact of pulverized coal combustion system on pollutant environment, and coal fly ash plays an important role in stable flame combustion.

4.3. Burning performance analysis

The combustion point of pulverized coal and coal ash at five temperatures of 10℃, 80℃ and 100℃ decreases with the increase of coal fly ash. As the ratio of coal pulverized coal and coal ash increases, the combustion stability decreases with the increase of pulverized coal added. The combustion points of the propellant at 10℃ decreases with the increase of pulverized coal. When the combustion point increases every 10cm-20cm-40kg, the combustion point decreases is due to the increase of pulverized coal, but the combustion point increases by the increase of the burned-out gas, resulting in the gradual increase of the total amount of fuel. Therefore, adding pulverized coal at 10℃ can improve the propellant fuel exhaust gas increase has little impact on the gas volume, but it will lead to a high total fuel gas volume value.

4.4. Combustion performance evaluation

The test yields the propellant fuel response to the combustion chamber temperature and oxygen concentration. When the pulverized coal content is 40%, The combustion chamber temperature varies very little, With the increase of the pulverized coal content, The combustion chamber temperature was gradually increased, The oxygen concentration was gradually decreased, When the pulverized coal content is 45%, Its combustion reaction rate begins to increase, Coal consumption begins to increase at 40% pulverized coal, The black smoke produced during the combustion process was gradually decreased, The oxygen concentration was gradually increased, When the pulverized coal content is 60%, Its combustion chamber temperature drops rapidly, Ox oxygen concentration increased rapidly, Thus producing a strong redox reaction, When the pulverized coal content is 60%, The combustion chamber temperature gradually increases, The oxygen concentration was gradually

decreased, Its combustion chamber temperature gradually decreases, The redox reaction rate is accelerated, This produces a large amount of black smoke. Therefore, it can be seen that the greater the amount of propellant, the better the combustion performance, but when the pulverized coal and pulverizing coal degree is large, its combustion performance is poor, and add the appropriate amount of pulverized coal to make its combustion performance is better. Propropellant fuel add appropriate amount of pulverized coal fuel can improve propellant mixture adhesion, reduce REDOX reaction rate and flame strength, reduce the soot concentration, its performance is better than burning coal, improve the safety of propellant fuel, but also has good combustion stability, no black smoke and no pollution to the environment, has a good market application prospect.

5. Brief Summary

In this study, the kneading machine was used for material mixing analysis, using the clay, stone powder, bentonite, sintering material, coal gangue, fly ash and cinder for mixing, and obtained the propellant with different sintering degree and particle size distribution. When the rotary roller mixture is mixed in the kneading machine, the propellant with bentonite is better than the traditional kneading machine, and the mixed fly ash and cinder will increase the propellant combustion temperature. The sintering ratio of the propellant increases; instead, the feed ratio of adding bentonite to the mixer increases and then decreases; rock and coke are the best configuration in fuel supply. The comprehensive analysis shows that the combustion performance of the propellant and the large amount of dust, nitrogen oxide and carbon monoxide during the mixing process produce more black smoke and dust during the propellant combustion. Therefore, propose propellant products that can be used in kneading paper.

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