The Combustion Performance and Ingredient Ratio of Thermite

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Abstract. Thermite was widely used because of its combustion properties and combustion products. However, due to the combustion heat, ignition performance, burning rate and the ratio of energy conversion of different components of thermite agent are very different. The requirements of the main realization in: (a) Its easy to ignite and not easy to extinguish; (b) Combustion and heat as much as possible High; (c) The burning speed should be appropriate. So the performance of these aspects is always being hot focus. In this paper, four aspects of the improve about combustion heat, ignition performance, burning rate and the ratio of energy conversion were analyzed through the aluminum alloy, the addition of aluminum, the addition of the third party, the change of the particle size and the compaction density. Finaly states the research direction in the future. The future of aluminum heat agent formula research focus will be: (a) A single aluminum heat agent the best proportion of the study; (b) The addition of different additives and additives (c) The exploration of alternatives that are more excellent performance will inevitably become a hot topic to improve the heat of combustion. Aluminum heat agent performance will be much superior, and the application will also be more extensive.

1. Introduction
Thermite is widely used because of its excellent performance of high temperature and the ability to produce molten metal. The initial range of thermit is narrow, indicating only Al/Fe₂O₃ applied at that time, however, with the expansion of the scope of application, resulting in a number of different application conditions and special needs. So as to improve the combustion performance of the new requirements, therefore need to change the aluminum heat agent formula to achieve the aluminum heat modified. All along, the aluminum heat agent components of the inquiry have never stopped. The aluminum heat agent combustion performance has become more and more in-depth.

2. Heat of Combustion

2.1 Single Aluminum Heat Agent
For different aluminum heat, the reaction heat is not the same, the following is the standard conditions of different oxide powder and aluminum powder reaction occurs when the reaction:

\[
\begin{align*}
2\text{Al} + \text{Fe}_2\text{O}_3 & \rightarrow 2\text{Fe} + \text{Al}_2\text{O}_3 + 856.6\text{kJ} / \text{mol} \\
2\text{Al} + \text{Cr}_2\text{O}_3 & \rightarrow 2\text{Cr} + \text{Al}_2\text{O}_3 + 535.6\text{kJ} / \text{mol} \\
2\text{Al} + 3\text{CuO} & \rightarrow 3\text{Cu} + \text{Al}_2\text{O}_3 + 1212.5\text{kJ} / \text{mol}
\end{align*}
\]
The above reaction exotherm is the standard molar reaction calorific value, which reflects the energetic size of each aluminum heat agent, for the choice of aluminum heat to provide a basic basis.

However, for the aluminum heat agent, only the high heat of reaction can not explain the high reaction temperature. Wang Yi and so on according to the principle of itching balance ratio, and through the use of sol/gel method prepared nano-Al/Fe$_2$O$_3$ Aluminum heat agent, measured the heat release of 1648J/g. Tillotson T M measured the total reaction heat of nano-Al/Fe$_2$O$_3$ at 1500J/g [1], and Wang Yi's conclusion is basically consistent. The molar value of the molar reaction is about 672 kJ/mol. Can be seen between the real heat and the ideal heat is still a big gap between. So simply press

According to the chemical reaction equation for a simple ratio does not necessarily achieve the best combustion effect. The difference in the composition of the main components will lead to different ignition temperature, burning speed and other factors, which lead to different macro temperature. So the single aluminum heat agent in the proportion of the study will still be an indispensable future important direction.

2.2 Mixed with a Variety of Aluminum Heat Agent
A single aluminum heat agent has a specific number of combustion properties, ignition performance, etc., when trying to mix different aluminum heat agent, the expected combustion performance can be a variety of aluminum heat agent characteristics of the integrated, to meet the needs of different occasions. CuO can produce a lot of oxygen during the reaction, and the reaction heat of Al/CuO is higher than that of iron-aluminum heat, and the metal jet produced by the reaction is more stable, but the unsuitable content is too high because the generated high pressure is prone to explosion. So the amount of hot cut can be appropriate reference. Al/Fe$_2$O$_3$ reaction speed is slow, and combustion stability, so suitable for the need for stable combustion in the occasion. Zhang Jing and so on by adjusting the cutting agent aluminum heat agent formula after the test concluded: Al/Fe$_2$O$_3$ burning point is too high, which can not produce the spray slag; Al/CuO burning speed is too fast, the pressure is too large; Al/Y (which is easy to ignite and generate high temperatures while reducing gas generation due to the absence of gas) can increase combustion heat and make combustion more stable; Al/Y increases its flammability due to its low ignition and the release of large amounts of heat Sex. When the above formula is controlled at 30%: 30%: 30%: 20%: 20% can achieve the best cutting effect. Similar experimental results, Wang Peng and so on through the experimental study of pyrotechnic cutting agent of the best melt metal aluminum heat agent formula: Al/Fe$_3$O$_4$ can reduce the combustion propagation rate, Al / CuO can produce high pressure oxygen to generate Metal copper jet, Al/X can produce a lot of heat to increase the system reaction temperature. When the content of Al / Fe$_3$O$_4$ is 30% ~ 50%, Al/CuO is 30% ~ 50%, then 10 ~ 20% Al/X is added, the melting effect is the best. Wang Sen [2] and so on through the inorganic thermodynamic analysis and calculation of the cutting agent aluminum heat agent formula to explore the choice of Al/Fe$_2$O$_3$ and Al/CuO mixture, Al/CuO in the mass fraction of 13.6% to 22.8% When the best cutting effect, Al/CuO is too high working time is too short, Al/CuO is too low temperature is not enough.

Shen Lianhua et al. determined the combustion properties of Al/B/Fe$_2$O$_3$ nanocomposite energetic materials. The results show that when Al content accounts for 80% of the reducing agent, B accounts for 20% of the reducing agent, that is, Al accounts for 44.3% of the total Al/B/Fe$_2$O$_3$ nanocomposites, 44.7% of Fe$_2$O$_3$, and 11.1% of the total mass. With a high reaction enthalpy.

It can be seen from the above, in the development of aluminum heat agent, the study of the combustion performance of different aluminum heat and the effect of mixed aluminum heat on the overall performance of the study more and more in-depth, aluminum heat agent performance will be more suitable for different areas The demand.

2.3 Change the Particle Size and Join the Third Party Material
In recent years, with the improvement of processing technology, nano-level metal particles have been greatly improved, and around the nano-level aluminum heat agent performance research also will be carried out, through the “super aluminum heat” is also known Scholars on the nano-aluminum heat agent affirmed.
Sullivan K [3] and so on by ultrasonic dispersion method in the Al/CuO aluminum heat agent added nano-B to test its performance and combustion performance, found that nano-B molar content of less than 50% can enhance its combustion performance. An Ting [4] with hydrothermal preparation of MnO$_2$ nanotubes and nano-aluminum powder as raw materials prepared nano-aluminum heat agent, combustion heat up to 6165kJ/kg. Since the hydrogen content in NaBH$_4$ is 10.66% [5], NaBH$_4$ has a significant effect on the improvement of combustion energy. In the formulation of the combustion machine, NaBH$_4$ is added to NaBH$_4$ by orthogonally The results showed that the addition of NaBH$_4$ could significantly increase the calorific value, and when the content of NaBH$_4$ was 20%, the increase was up to 14.3%. It can be seen that changing the particle size and the addition of additives to the heat of the aluminum heat of the heat can be seen in the future will inevitably become a hot way to improve the heat of combustion.

3. Ignition Performance

Aluminum ignition agent ignition temperature is high, not easy to ignite, resulting in the practical application of ignition is not very convenient, which to some extent limit the aluminum heat agent as a promotion of combustion, so reduce the ignition temperature for the application of aluminum heat Extraordinary meaning.

3.1 Single Aluminum Heat Agent

For a single aluminum heat agent, by changing the content of some ingredients in the formula, to achieve the purpose of improving the ignition temperature is a more direct and effective method. For the aluminum heat agent in a major component - the effect of oxidant changes on the combustion performance, is the focus of discussion of scholars. Xue Yan prepared Al/MoO$_3$, and its combustion heat is 8351J/g, and the impact sensitivity is low, the flame sensitivity is more sensitive. Zheng Baoming [6] and so on according to the reaction product integrated DSC curve analysis KMnO$_4$ in aluminum thermal reaction in the actual reaction is KMnO$_4$ decomposition products MnO$_2$. And Li Qianqian [7] and so on with frozen ball milling method prepared Al/MnO$_2$ composite powder, and that it is more than other methods of preparation of the degree of mechanization activity is higher, more reactive, the reaction heat release is also significantly increased.

For the effect of aluminum powder on the ignition performance, Umbrajker [8] and so on by measuring the ignition temperature of Al/MoO$_3$ system found that at the same heating rate, the ignition temperature with the Al content increases, the ignition temperature will be increased. Similarly, Bazyn [9] et al through the shock wave ignition experimental study found that: Al-MoO$_3$ ignition delay period with the increase in Al content and longer. It can be seen that the impact of aluminum powder for the same positive correlation for the aluminum heat agent ratio provides a basis.

With the development of scientific research, the understanding of various raw materials continues to deepen. At the same time due to the complex process of nano-aluminum powder preparation, so there has been a substitute for Al powder exploration, France [10] carried out on the nano-P/CuO aluminum heat agent research, found that the aluminum heat agent impact sensitivity moderate, Sensitivity and electrostatic fire sensitivity is high, similar to conventional detonating drugs, and red phosphorus is easy to obtain, and more easily oxidized, and CuO reactivity stronger, so it is expected in the future a lot of applications. The future for more excellent performance of the alternatives will be an important development direction.

3.2 Change the Particle Size and Join the Third Party Material

Bazyn [11] et al through the shock wave ignition experiments found that: nano-Al powder delay period for the microsecond; and micron-level Al powder delay period is longer, in milliseconds. Indicating that the use of nano-level of raw materials easier to ignite. This indicates the direction of the ignition modification of the nano-scale aluminum heat agent.

It is possible to reduce the ignition temperature of the aluminum heat agent by adding some substances which are relatively easy to ignite in the aluminum heat agent and which can produce a
higher temperature to ignite the aluminum heat agent. According to the Al-Mg/KMnO$_4$ aluminum heat, it was found that when the content of Mg was higher, the lower the ignition temperature and lower from 723K to 493K. Zhou Jianzhong [12] and so on in the aluminum heat agent by adding Si-Bi$_2$O$_3$ mixture can increase the heat of aluminum heat agent while reducing the ignition temperature, and when the content of 20% when the minimum ignition temperature of 613 °C. France [13] developed a kind of aluminum in the aluminum alloy by adding a special structure of graphitized carbon black can reduce the sensitivity of aluminum heat agent. All of which illustrate the third-party material for the ignition temperature reduction has a very important role.

3.3 Density
The pressing density is also one of the factors affecting the ignition delay period. Stamatis [14] prepared by the ARM method 8Al-MoO$_3$ system of nano-aluminum heat agent pressed into a high-density cylinder, the laser beam as the ignition source to test its reactivity. The results show that the ignition delay period becomes longer with the pressing density. The higher the pressing density leads to the higher the thermal conductivity, the greater the specific heat, resulting in longer ignition time.

4. Speed of Burning

4.1 Single Aluminum Heat Agent
Al powder as a reducing agent for aluminum thermal reaction, its impact on the combustion rate has always been taken into account. Prakash [15] the effect of Al/KMnO$_4$ on the combustion performance was determined by the difference in the mass fraction of Al/KMnO$_4$. When the mass fraction of Al was 35%, the reaction rate reached the highest. Dutro GM [16] prepared nano-Al/MoO$_3$ aluminum heat agent, and by changing the composition of these different components into the combustion tube and found: When the mass of Al from 10% to 65%, the aluminum heat agent combustion reaction Speed from 100m/s stability to 1000m/s; greater than 85% or less than 10% are not a good reaction rate. It can be seen that Al powder has a significant effect on the burning rate of aluminum heat.

4.2 Adding Third Party Material
Third-party material can change the microstructure of aluminum heat agent composition, as the intermediate reaction medium and produce gas pressure to speed up the reaction rate and so on. Yang [17] et al. prepared nano-Al powder coated MnO$_2$/SnO$_2$. Experimental results show that the reaction temperature is reduced, because SnO$_2$ can reduce the surface free energy of MnO$_2$, make nano-Al and contact MnO$_2$ more closely, Increase the delivery speed. Wang Zhi and so on by adding NaF in Al/Fe$_2$O$_3$, found that with the increase of NaF, the rate of self-propagation decreased first and then increased, the early part of the absorption of heat, play a role in reducing the reaction, the latter is F The role of ions on the surface of Al on the destruction of Al$_2$O$_3$ play a role in the destruction of hormones. Wang Sen [18] and so on through the test to determine the impact of KNO$_3$ on thermally cutting ammunition, in the isovolumetric environment, due to the presence of KNO$_3$ gas pressure, which will speed up the burning rate, but the resulting slag spray will have a favorable impact on cutting. The experimental results show that when KNO3 is 4.8% ~ 7.8%, the cutting effect is the best.

4.3 Change the Particle Size
The contact area between the nanomaterials is large, so the conduction rate of the reaction increases. This is also true for aluminum heaters. Sun J [19] et al. studied the thermal behavior of Al/MoO$_3$ prepared with different sizes of Al powder particles. The results show that the activity of nano-Al particles is higher than that of microns, and with the increase of nano-Al particle size The reaction rate increases. Weismiller MR [20] et al. prepared Al/CuO and Al/MoO$_3$ nano-aluminum heat by the method of physical mixing. The experimental results show that the combination of nano-Al powder and nano-oxide is the fastest. Comparative experiments show that nano-oxide nano-Al powder than the contribution of the contribution rate of large. In the test of Al/B/Fe$_2$O$_3$ combustion performance, it was
found that the nanocomposite Al/B/Fe2O3 was 6 times higher than the physical blends of Al/B/Fe2O3, and the sensitivities were obviously more than physical blends Al/B/Fe2O3 low.

5. Rate of Energy Conversion
For a substance, the size of its utilization determines the level of efficiency, for enterprises, the savings and reduction of raw materials related to the vital interests. Therefore, the size of the energy conversion rate for the efficient use of aluminum heat and the actual application of the amount of loading has a crucial role. Umbrakkar [21] et al. measured the atmospheric pressure change by constant ignition test to estimate the energy conversion efficiency in the Al/MoO3 combustion process. The results show that when the ratio of raw materials is 4 and 8, the energy conversion efficiency is much higher than that of aluminum powder. When the ratio of raw materials is 12 and 16, the energy conversion efficiency nanometer Al powder is equivalent, and the reason is aluminum high, the greater the particle size of the complex, leading to this phenomenon. Schoenitz [22] et al through experimental studies found that Al/MoO3 in the raw material ratio of 8, the fastest energy release rate. Stamatis [23] et al. demonstrated that the energy conversion effect was best when the 8Al-3CuO complex with a mass fraction of 20% was added to the pure aluminum powder. Thus, Al powder on the aluminum heat of the energy conversion rate also has a significant impact.

6. Discussion and Prospect
The main combustion properties of aluminum heat agent include combustion exotherm, ignition performance, burning rate, energy conversion rate, etc. The requirements of the main realization in: (a) Its easy to ignite and not easy to extinguish; (b) Combustion and heat as much as possible High; (c) The burning speed should be appropriate. The improvement of the above performance is mainly through the size of the raw material, oxidants, reducing agents and additives selection and the ratio, compaction density and other aspects of the change to achieve, so the study of aluminum heat agent on the need for a large number of Experiment to support.

With the understanding of the types and properties of materials continue to deepen, the future of aluminum heat agent formula research focus will be: (a) A single aluminum heat agent the best proportion of the study; (b) The addition of different additives and additives (c) The exploration of alternatives that are more excellent performance will inevitably become a hot topic to improve the heat of combustion. Aluminum heat agent performance will be more and more superior, the application will also be more extensive.

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