Packaging category and its influencing factors of potassium nitrate

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Abstract: To understand the combustion characteristics of potassium nitrate and evaluate the magnitude of combustion risk, oxidation solid test apparatus is used and the updated experimental criterion of the United Nations is adopted to measure the packaging category of potassium nitrate. The new criterion puts calcium peroxide and microcrystalline cellulose as references and burning rate as evaluation index. Effects of mixing ratio and insert medium on burning rate are reached. Test results show that pure potassium nitrate doesn't burn under normal temperature and pressure, however, its oxidation is very strong and the packaging category should choose the class I. As the mass fraction of potassium nitrate reduces, the burning rate first increases and then decreases. When the ratio is 2 : 1, the combustion rate reaches the maximum, and the effect of combustion is the best. When 1 : 3, the combustion rate is the minimum. The mixture combustion can be suppressed by silicon dioxide and hydrogen phosphate, which is not fired when silica concentration is 40% or ammonium hydrogen potassium phosphate is 55%, their effects are very obvious.

Key words: potassium nitrate; packaging category; mixture ratio; inert medium; combustion rate

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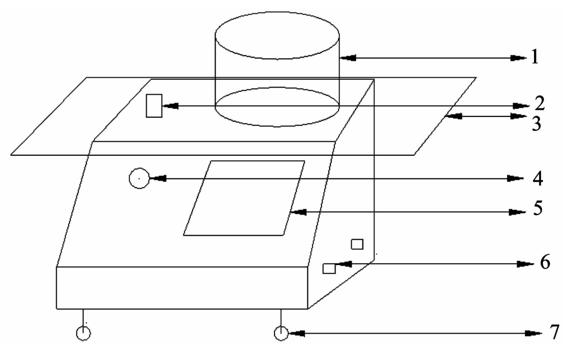
Potassium nitrate has oxidation property, which can occur fire when it meets combustible materials, and the reaction will produce a large number of harmful substances, so it is necessary to study its packaging level. In recent years, researches related to oxidation property are made in solution. As to the solid, people still use the judging standards of "on the transports of dangerous goods proposal" written by United Nations Economic and Social Council, in which potassium bromate and stem cellulose fiber are used as references, and burning time as judge standard. So far, there are few studies on the measurement of new method. JIANG Xin et al. [1] studied the oxidation of solid test and judging method improvement, in which they compared the old with new method, and determined the packaging categories of several oxides except potassium nitrate. This article uses new method to measure the package level of potassium nitrate, and determines the effects of concentration and inert medium on the combustion rate in order to provide some theoretical guidance.

1 Experimental principle

1.1 Schematic diagram of experimental device



1— Wind shield; 2—Heating wire like mold;
3— Acrylic protective plate; 4— Switch button;
5— Display; 6— USB interface; 7— Foot

Fig. 1 Solid oxidation test apparatus

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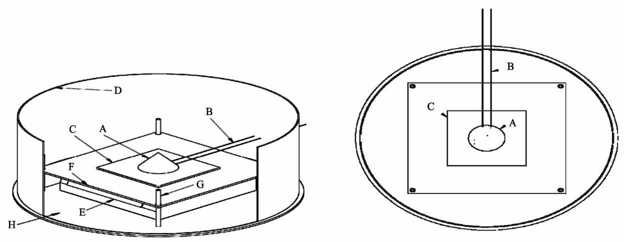

A — Conical stacing; B — Home hotline; C — Test board;
D — Wind shield; E — Balance with connection interface;
F — Positioning plate; G — Guide rod for fixing a positioning plate and a test board in the specified positio of the balance;
H — Substrate

Fig. 2 Front view and vertical view of experimental configuration

1.2 Experiment reagent

Introduction of reagents used in this study: calcium peroxide: analysis of pure; microcrystalline cellulose: white powder, qualified particle size; potassium nitrate: analysis of pure; inert medium: silica and ammonium hydrogen phosphate.

1.3 Experimental sample preparation

The total weight of the experimental sample is 30 g, and the list is shown in Table 1.

Table 1 Experimental sample

Name	Component	Ratio
Test mixture	Potassium nitrate: cellulose	1 : 1
Test mixture	Potassium nitrate: cellulose	4 : 1
Class Ⅰ packaging mixture	Calcium peroxide: cellulose	3 : 1
Class Ⅱ packaging mixture	Calcium peroxide: cellulose	1 : 1
Class Ⅲ packaging mixture	Calcium peroxide: cellulose	1 : 2

1.4 Experimental procedure

The experimental device has a balance which can record at least five data per second. Incendiary source is nickel mental wire. First, samples are weighed according to the predetermined proportion and stired evenly. Second, the nickel wire is formed on the molding machine. Third, the instrument is opened and calibrated. Fourth, the wire is heated and placed on the burning plate. Fifth, the sample is placed and test is started. Sixth, the experimental data is saved.

1.5 Experimental evaluation criteria

Comparing the burning rate with Ⅰ object of reference, Ⅱ object of reference and Ⅲ object of reference, if it is greater than or equal to the Ⅰ, the packing grade should choose Ⅰ; if it is greater than or equal to Ⅰ but less than or equal to Ⅱ, the packing grade should choose Ⅱ; if it is greater than or equal to Ⅱ but less than or equal to Ⅲ, the packing grade should choose Ⅲ.

2 Experimental results and analysis

2.1 Measurement results of calcium peroxide

When the calcium peroxide is burning, the phenomenons of different proportions are different. Increasing the mass percentage of calcium peroxide, the combustion is more vigorous, burning rate is faster and flame is violent with strong smoke. The results are shown as follow in Table 2.

Table 2 Changes of burning rates with ratios of calcium peroxide and cellulose

Times	Ratio		
	3 : 1	1 : 1	1 : 2
1	1.040 1	0.261 5	0.152 4
2	0.980 0	0.251 8	0.173 1
3	1.125 1	0.400 6	0.162 8
4	1.096 7	0.310 3	0.180 2
5	0.962 3	0.324 1	0.172 9
Average	1.040 8	0.309 6	0.168 3

2.2 Measurement results of potassium nitrate

The experiment is carried out five times according to two proportions. When the ratio is 1 : 1, the potassium nitrate burns rapidly after ignited, and produces thick smoke, bright flame and spatter combustion. Moreover, it is accompanied by strong pungent odor, and the mixture becomes black residue after 15 s. When cleaning up experimental instrument, the burning plate is heated obviously and the mixture is solidified on the burning plate, which show that the reaction is complete and thorough. When the ratio is 4 : 1, the mixture does not burn after ignited, only a small amount of gray smoke, sporadic mars and pungent odor, and combustion period is shorter. Moving close to observe, it can be found that most mixture is white, only little black burnt powder sticking to the nickel wire, basic no combustion. The results of the experiment are as follow in Table 3.

Table 3 Test results of burning rate of potassium nitrate

Times	Ratio	
	1 ∶ 1	4 ∶ 1
1	1.933 9	1.266 7
2	2.096 3	1.030 0
3	1.876 2	1.123 5
4	2.052 4	1.069 1
5	1.962 0	1.010 9
Average	1.984 2	1.100 0

Tables 3 and 2 are carried out under one bar pressure, 15 ℃. Comparing their burning rates, we know that not the proportion is greater, the burning rate is faster. When the ratio is 1 ∶ 1, the burning rate is 1.984 2 g/s; when the ratio is 4 ∶ 1, the burning rate is 1.100 0 g/s, which is greater than Ⅰ packing reference material, so the packaging of potassium nitrate should be class Ⅰ.

Clearing the packaging category is beneficial to decreasing fire and explosion accidents. when storing it, we must be in accordance with the requirements of the class Ⅰ to realize transportation security. This method can be also used to determine other commonly oxides, because its experimental time is short and the operation is relatively simple[2].

3 Research on influencing factors

3.1 Effects of mixture ratio on combustion rate of potassium nitrate

Potassium nitrate with microcrystalline cellulose mixed according to the ratios of 3 ∶ 1, 2 ∶ 1, 1 ∶ 1, 1 ∶ 2, 1 ∶ 3, the total weight is 30 g. To measure the burning rate respectively, each data is measured three times and the average value is obtained. The results are shown in Fig. 3.

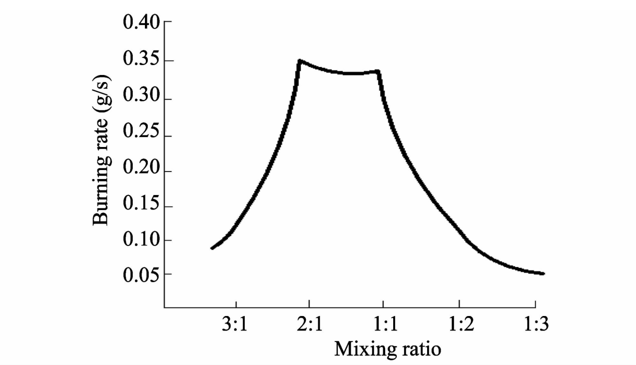

Fig. 3 Effect of mixing ratio on combustion rate

As we can see from the Fig. 3, the burning rate increases first and then decreases with the decreasing of mass fraction of potassium nitrate. When the ratio is 2 ∶ 1, burnable flame is the most violent. When the concentration of potassium nitrate is reduced, burning rate decreases rapidly. When the ratio is closed to 1 ∶ 3, the rate tends to be steady, that is to say the combustion effect of potassium nitrate is not obvious at this moment[3-4]. The reasons are that, firstly, potassium nitrate is much more than microcrystalline cellulose, and its molecelar surface area is larger too, so a large amount of microcrystalline cellulose are wrapped by potassium nitrate. However, potassium nitrate does not burn itself, so the rate is slow, and the product of combustion is white almost[5]. Secondly, with the growing number of microcrystalline cellulose, potassium nitrate releases oxygen to promote the combustion, produces fierce flame, what is more, the products quickly become black until complete combustion[2-3].

3.2 Effects of inert medium on burning rate of potassium nitrate

This experiment chooses two kinds of inert media, silicon dioxide and ammonium dihydrogen phosphate, to research their influence on the burning rate respectively. The ratio of potassium nitrate and microcrystalline cellulose is 2 ∶ 1, experimental results as shown in Fig. 4.

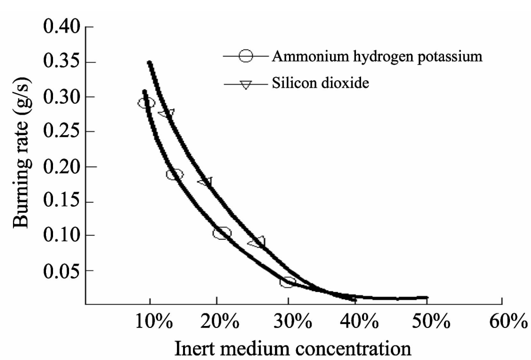

Fig. 4 Influence of concentration of inert medium on combustion rate

As we can see from the Fig. 4, the inhibitory effect of ammonium dihydrogen phosphate is more obvious than silicon dioxide. The reasons are that ammonium dihydrogen phosphate can not only inhibit the burning of mixture through its own physical heat absorption, but also produce water vapor by chemical reactions to absorb the free radicals and form the protective tissue to inhibit the combustion. In the later period, the inert medium is still remaining with the increasing of concentration, which leads to the nonflammability of mixture[6-9].

4 Conclusions

1) Using calcium oxide and microcrystalline cellulose as reference materials, we get that the packing category of potassium nitrate should choose class Ⅰ.

2) With different ratios of potassium nitrate and microcrystalline cellulose, the burning rates are different. When decreasing the potassium nitrate, the burning rate increases first and then decreases, which reaches the maximum when the ratio is 2∶1, and reaches the minimum when the ratio is 1∶3.

3) The inert medium can suppress the burning rate. For ammonium dihydrogen phosphate and silicon dioxide, their effects are obvious. However, the former can extinguish the fire when its concentration is 55% , and the later is 40%.

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硝酸钾包装类别的测定及影响因素研究

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摘 要： 为了解硝酸钾的助燃特性，以评价其燃烧危险性，本文利用氧化性固体试验仪，基于联合国最新的实验判定标准，以过氧化钙和微晶纤维素作参照物，以燃烧速率做评判指标，测定了硝酸钾的包装类别，并研究了混合比例和惰性介质浓度对其燃烧速率的影响。结果表明：常温常压下纯硝酸钾并不燃烧，但其氧化性极强，其包装类别为Ⅰ类。随着混合物中硝酸钾质量分数的减少，混合物燃烧速率先增大后减小。当混合比例为 2∶1 时燃烧速率最大，助燃效果最好，混合比例为 1∶3 时燃烧速率最小，助燃效果最差。惰性介质中二氧化硅、磷酸二氢铵都可以抑制混合物的燃烧，当二氧化硅浓度为 40%时混合物未被点燃，当磷酸二氢铵浓度为 55%时混合物未被点燃，二者抑制效果都很明显。

关键词： 硝酸钾；包装类别；混合比例；惰性介质；助燃速率

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