The research and development of heat insulation materials with low thermal-conductivity in high temperature

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Abstract. The important tendency of the new style heat insulation materials is the research and development of the composites which have low thermal-conductivity in high temperature. The characteristics of the alumina-silicate fibre with $K_2Ti_6O_{13}$ whiskers and SiO_2.aerogel are discussed in this paper. Finally, several future developing directions for heat insulation matrrials with low thermal conductivity in high temperature are suggested.

Introduction

New heat insulation material has been widely used in aerospace, energy, chemical and metallurgical industries, An important development trend is the research and development of composite function of heat insulation materials with low thermal conductivity. The general heat insulation material has excellent heat insulating property, but the lack of high temperature strength. Therefore, refractory and heat insulation material with excellent thermal insulation properties and high temperature strength of composite function has become a new hotspot. The key technology is how to coordinate and balance the insulation properties and high temperature strength of these two mutually constrained properties in materials design and technology research[1].

In order to obtain the high strength and low thermal conductivity of composite insulation materials, The species and the composition of material need to change, Using different binder and adding amount, Study on the relationship between the material formulation, process parameters and heat insulation effects, The material's formula is Optimized, Determine the composition structure of the new type of composite insulation materials[2]. This paper mainly discusses the characteristics of the current several heat insulation materials used, And puts forward several development directions of composite insulation materials with high temperature low thermal conduction.

The characteristics of kinds of heat insulation materials

Aluminum silicate fiber

Aluminum silicate refractory fiber as high-temperature insulation material and refractory material has a long history. In recent years, This material is used as a heat insulation material used to prepare new thin ceramic fiber composite material thermal insulation, widely used in aerospace industry. Especially in the insulating parts with the requirement of the light quality and occupy the limited space, This material has been the most effective use , achieveing the ideal effect of thermal protection. With aluminum silicate as articles base ceramic fiber can be made into various forms of products, such as, Fiber mat, fiber board, fiber paper, fiber rope and various kinds of fabrics [3]. In the field of Aerospace, Aluminum silicate fiber insulating layer composite materials have been used as a rocket engine components,Oxygen generator insulation etc. used as the leading edge of the wing and end cap ablative protection layer in the military and commercial aircraft, fire protection layer of various instruments and equipment on the aircraft[4,8].

Compared with other insulating refractory, Aluminum silicate fiber has very small volume density, specific heat, thermal conductivity and particularly good resistance to temperature rapid change, the using temperature higher than 1200℃. If the right amount of alumina fiber is joined, the

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use of temperature can be higher.

Aluminum silicate fiber raw materials used in this experiment is the oil stained cotton provided by the Shandong Lu yang Limited company. It is the production process of ceramic in cotton， and the chemical composition and physical properties is showed in table 1 and table 2.

Table 1 Chemical composition of aluminum silicate fiber

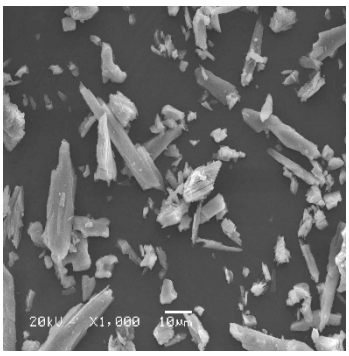
Al_2O_3 (%)	SiO_2 (%)	Fe_2O_3 (%)	K_2O+Na_2O (%)
48.93	49.59	0.98	0.50

Table 2 Physical properties of aluminum silicate fiber

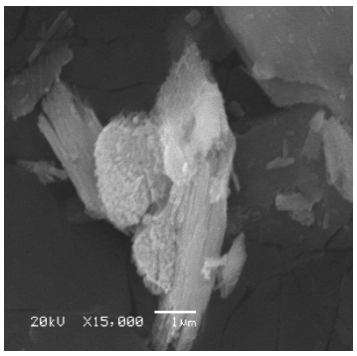
fiber diameter (μm)	fiber length (mm)	High temperature shrinkage(%) (1150℃×6h)	Therma lconductivity (W/M·K)
2～4	50	3.6	0.13～0.15

Six potassium titanate whisker

Six potassium titanate whisker ,Chemical formula $K_2O \cdot 6TiO_2$. Six potassium titanate whisker diameter is 0.1μm-1.5μm, Length 10μm-100μm. Because the gaps aluminum silicate fiber formed in the framework is relatively large, A single six potassium titanate whisker is difficult to attach in the fiber, So we don't broken Six potassium titanate whisker, But the use of aggregates of Six potassium titanate whiskers.



a)



b)

Fig.1 SEM photograph of $K_2Ti_60_{13}$ whiskers

Figure 1 a) shows the micro morphology, Six potassium titanate whisker shapes rod irregular aggregates, with different ratio of length to diameter. In order to directly and accuratly observe and describe the whisker surface state and the structure of aggregates, We use Japanese electronic scanning microscope JSM-100c, Under the voltage of 20KV, The whiskers were observed in 2000 times magnification, as shown in Fig 1b),We can see that, After the structure of whiskers like tunnel gatheres together, the tree hole structure with numerous micropores will be formed.

Nanoporous silica insulation materials

There are reports that the thermal conductivity of the stationary state of air and most gases such as oxygen, N_2, CO_2 two is very low, But due to their convection and transparent to infrared radiation, So they cannot separately as thermal insulation material. Therefore, we need to design a structure to maximize limit their performance of convection and infrared performance, This kind of structure is generally helped to realize with the use of some solid materials, However, Coefficient of thermal conductivity of almost all solid materials are still much larger than gas, Therefore, in the implementation of this structure should be to minimize the use of solid materials. Imaginig that these voids size limit to the nanometer order of magnitude, The conduction and convection of gas will basically be controlled, The coefficient of thermal conductivity of this kind of heat insulating material will be lower than in still air.

Aerogel is a new type of nano porous materials with a controllable structure, With powder and bulk, The hole rate is up to 80% ~ 99.8%, the specific surface area up to 800～1 000m2•g-1 , the

typical pore size is 1~100 nm. Solid state structural unit of network size is 1-20 nm. Due to the nano porous network structure, its solid and gaseous heat conduction is very low. Adding infrared shading agent can effectively block the infrared radiation, The total thermal conductivity at room temperature, atmospheric pressure ratio as low as0.01W•m-1•K-1 , the lowest thermal[9, 11]conductivity in the solid material at present[12,13].

The development prediction of insulation material with high temperature Low thermal conductivity

Multilayer composite thermal insulation material matched suitable improves heat insulation effect of the original single material, The thermal conductivity decreases, In view of the multi-functional development of heat insulation materials in the military and aerospace fields,

The development of insulating composites based aluminum silicate fiber six potassium titanate whisker as additive.

Insulation materials have the characteristics of gravity and small coefficient of thermal conductivity, ablation resistance etc, So the choice of suitable fillers has the decisive effect on the performance of materials t[14]. The coefficient of thermal conductivity of aluminum silicate fiber material is increases with the increase of the temperature of use, The use of high temperature(More than 800℃), Radiation heat transfer between fiber surface and heat conduction of air in the pores of aluminum silicate fiber materials are correspondingly enhanced. The use of higher temperature, the proportion of radiation heat transfer is the greater. In the Process of high temperature heat transfer, Gas radiation heat transfer effect and its effect is very important[15].

therefore heat insulation performance of aluminum silicate fiber products are not up to the environmental requirements under high temperature sometimes, Having high temperature and low thermal conductivity of aluminum silicate fiber products become a promising performance, Six potassium titanate whisker can resist high temperature of 1200℃, The infrared reflectivity is high, Because the six potassium titanate whisker has a negative temperature coefficient, That is, the thermal conductivity decreases with the increase of temperature, 800℃. only 0.017W/M•K. So we can make full use of high temperature and excellent thermal insulation properties of six potassium titanate whisker. As a heat insulation additive used in the forming process of the rate of silicate fiber products.

The use of nano microporous structure of SiO_2 aerogels, infrared shading performance of six potassium titanate whisker

Maximum use temperature of SiO_2 aerogel reaches as high as 1000 ℃, The coefficient of the annihilation of the infrared and visible light of the ratio can reach more than 100. The optical refractive index is close to 1, Therefore, under normal temperature, silica aerogel with high transmittance, have a good effect on infrared shielding, has the obvious characteristics of transparent insulation materials, Unfortunately, SiO_2 aerogel has good transparency on high temperature near infrared radiation, So in order to reduce the radiation heat transfer material, It is necessary to the incorporation of suitable infrared shielding agent, Six potassium titanate whisker is a kind of excellent infrared shielding agent, Silica aerogel evenly blending six of potassium titanate whisker can reduce infrared radiative transfer to a very low level.

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