Low Temperature Sintering Glass Binder for Al_2O_3 Grinding Wheel

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Abstract

K_2O-Na_2O-B_2O_3-Al_2O_3-SiO_2 glass was prepared by traditional melt cooling method, and the characteristic temperature of the as-obtained glass analyzed and its thermal stability evaluated. Use as-prepared glass as binder, the influence of sintering temperature on flexural strength of the corundum wheel specimens has been studied. The results show that K_2O-Na_2O-B_2O_3- Al_2O_3-SiO_2 glass has a low flow temperature of 853 °C and excellent thermal stability at 840 °C. When sintering temperature is 840 °C and the holding time is 10 h, a corundum wheel with flexural strength up to 46.83 MPa can be obtained. The huge energy saving in the sintering process will expect to bring significant benefits to the industrial production of corundum wheel.

Keywords

Binder; Glass; Al_2O_3 Grinding Wheel; Flexural Strength.

1. Introduction

Corundum wheel, as one of the most commonly used abrasive, is made of synthetic Al_2O_3 abrasive particles bonded together in a bonder to form a regular shape. The common binders include ceramics [1, 2], glasses [3], glass-ceramics [4], resin binders and other types [2]. Due to low cost and simple preparation process, the ceramic binder is the most commonly used binder for the preparation of corundum wheel. However, as a kind of physical mixture, the ceramic bonding agent is usually obtained by mixing and milling many ceramic raw materials. It is hard to achieve micro-level homogeneity just by milling, thus the inhomogeneous composition of bonding agent is inevitably. The inhomogeneous composition leads the formation of different phase after sintering at high temperature, resulting in the diversity of local microstructure, which will weaken the performance stability of the grinding wheel. In addition, in order to achieve sintering of the grinding wheel, a temperature higher than 1200 °C [2] is usually required to generate a liquid phase, so the high energy consumption is a big drawback of the ceramic binders.

The glass binder is regarded as an idea matrix material for grinding wheel, which have at least two obvious advantages, including better uniformity and lower firing temperature than ceramic binders. Glass binders are cooled by a high-temperature melt, and the liquid phase formed at high temperatures sufficiently homogenizes the various components in the glass to a "molecular" level, so the glass is theoretically homogeneous microscopically. Moreover, the energy required to produce a liquid phase in glass binder is much less than that of ceramic, even if the chemical composition is the same. Therefore, the use of glass as a wheel bond can not only theoretically reduce the firing temperature but also obviously improve the performance stability of the grinding wheel [1, 2].

In the present work, the feasibility of using low-temperature glass of K_2O-Na_2O-B_2O_3-Al_2O_3- SiO_2 as binder for corundum wheel was discussed, the appropriate sintering temperature range and the influence of firing temperature on the flexural strength of grinding wheel samples were explored. This study may provide a theoretical guidance and an experimental evidence for the production of corundum wheel under low temperature.

2. Experimental procedure

2.1 Raw materials and sample preparation

The K_2O-Na_2O-B_2O_3-Al_2O_3-SiO_2 glass, with the chemical composition listed in Tab. 1, were melted from analytical grade K_2CO_3, Na_2CO_3, B_2O_3, Al_2O_3 and SiO_2. Batches of about 600 g were mixed well in alumina containers with a planetary type-grinding machine for 2 h without any mixing medium. The glass batch was melted in an alumina crucible at 1420 °C for 2.5 h in air atmosphere. Glass slag was obtained by pouring the homogeneous melt into water, and then the glass slag was further grinded into glass powder by electric grinder. The size of glass powder is controlled less than 40 um.

Tab. 1 the chemical composition of the glass binder /wt %

SiO_2	Al_2O_3	Li_2O	B_2O_3	Na_2O	K_2O	MgO	ZnO	BaO
45	11	3	12	11	11	2	3	2

2.2 properties measurement of the glass binder

In order to provide a temperature reference for the firing conditions of the glass-bonded grinding wheel, the high-temperature softening test is carried out with a column specimen in size of Φ3 mm × 3 mm, which was made by pressing the glass powder into a mold. To evaluate the crystallization stability of the glass binder, XRD testing was performed on the glass specimens that has heat-treated at 900 °C for 10 hours.

2.3 preparation of the grinding wheel sample and performance testing

A mixture was mixed well with glass powder 50 g, yellow dextrin powder 1 g and water 20 ml. 200 g corundum abrasive with size of 200# was added into the mixture and continue to mix evenly, followed by pressure into rectangular specimens with size of 6 mm × 6 mm × 40 mm, the molding pressure was 20 MPa. The molded specimens were sintered at different temperature by a SiC electric furnace, the heated speed is set as 5 °C / min. The flexural strength of these sintered specimens were determined by an electronic universal testing machine (Model: WDW-100, Letry, China) with a span of 20 mm.

3. Results and discussion

In order to obtain sufficient strength of the sintered abrasive, the molded body needs to be sintered at a high temperature to form a certain proportion of liquid phase, to achieve wetting and wrapping of the abrasive grains. This requires that the sintering temperature for abrasives should be reasonable. If the sintering temperature is too low, the binder cannot produce liquid phase, thus the bonding of abrasive particles cannot be achieved. On the other hand, if the sintering temperature is too high, the binder is prone to plastic flow at high temperatures, leading to the deformation and size instability during the sintering process [4, 5]. In order to obtain a suitable temperature for the grinding wheel firing, a characteristic temperature analysis of the binder is required. Fig. 1 is the projection of the column specimen molded from glass powder at different temperature. It can be seen that the binder sample has a deformation temperature of 722 °C, a hemisphere temperature of 784 °C and a flow temperature of 853 °C. This indicates that the sintering temperature higher than 853 °C is required to produce a liquid phase, to form a good combination with the abrasive particles.

The flexural strength of the abrasive specimens sintered at different temperature is list in Tab. 2. Two specimens are tested for every sintering temperature, and the average strength values are given in the Tab. 2. An obvious increase trend of flexural strength with the increase of sintering temperature can be observed in Tab. 2. Fig.2 shows the influence of sintering temperature on the flexural strength of prepared specimens. It can be seen from the Fig. 2 that there is a clear linear relationship between the sintering temperature and the strength of the abrasive specimens, suggesting that a higher sintering temperature is help to improve the strength of the abrasives. However, based on the characteristic temperature of the glass binder, possible deformations and dimensional changes will occur when the sintering temperature is higher than the flow temperature. Therefore, the most suitable sintering temperature is 840 °C and the hold time is 2 h.

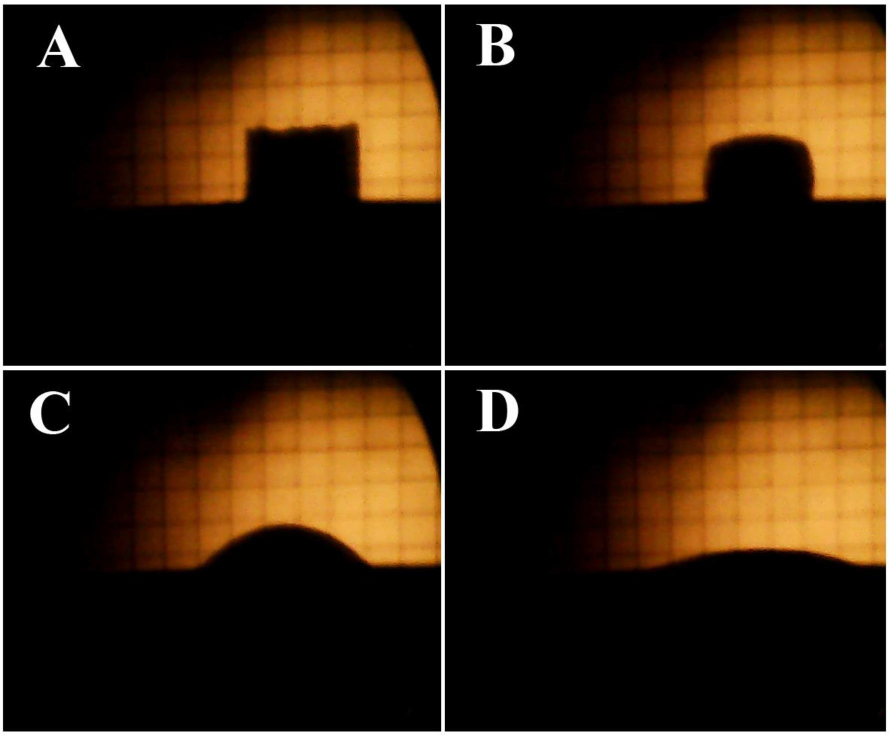

Fig. 1 the character temperature of glass binder: (A) 25 °C; (B) 722 °C; (C) 784 °C; (D) 853 °C

Tab. 2 Flexural strength of the abrasive specimens sintered at different temperature

Temperature /° C (×2h)	Sample No.	F /N	d /mm	a /mm	h /mm	σ /Mpa	Average σ /Mpa
750	A1	582.35	20.00	10.54	7.90	26.56	23.57
	A2	449.65	20.00	10.50	7.90	20.59	
780	A1	787.25	20.00	10.54	7.94	35.54	34.42
	A2	784.65	20.00	10.62	8.16	33.29	
810	A1	971.05	20.00	10.52	7.80	45.52	40.80
	A2	763.40	20.00	10.54	7.76	36.08	
840	A1	1051.35	20.00	10.52	8.32	43.31	46.83
	A2	1125.40	20.00	10.48	8.00	50.34	
870	A1	1508.85	20.00	10.48	9.00	53.32	50.23
	A2	1260.40	20.00	10.50	8.74	47.14	
900	A1	1313.05	20.00	10.64	7.76	61.48	62.23
	A2	1480.10	20.00	10.64	8.14	62.98	

According to thermodynamics, due to their energetic instability, glasses are potentially convertible to crystals under high temperature [6]. This phase transformation will inevitably lead to the microstructure change of the binder, resulting in a devastating effect on the stability of the abrasive performance [7]. In order to monitor the thermal stability of the glass binder, a long time heat treatment was carried out at 840 °C for 10 h. Then the XRD pattern of the specimen before and after heat-treating was obtained. Fig. 3 is the XRD patterns of glass binder (A) and the glass binder heat-treating at 840 °C for 10 h (B). As to be expected, the glass powder for the binder of grinding wheel has a broad peak, confirming its amorphous nature. It is worth nothing that the heat-treating specimen has a similar peak as the un-heated one, indicating the excellent thermal stability of the glass binder.

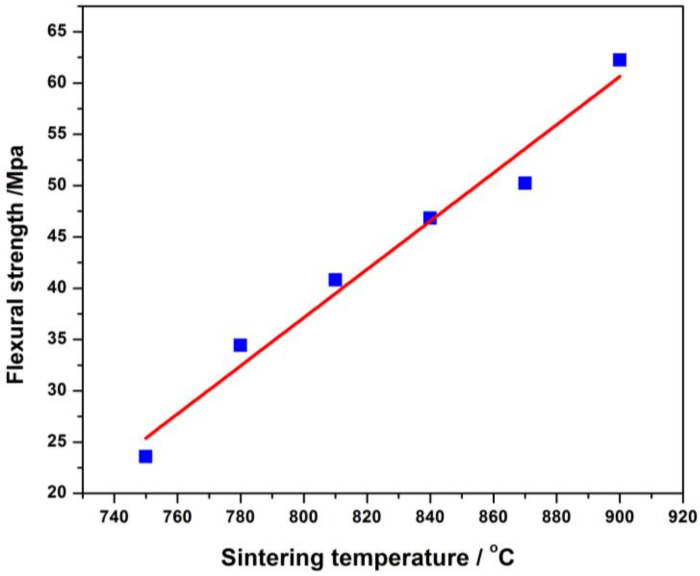

Fig. 2 the relationship between sintering temperature and flexural strength of specimens

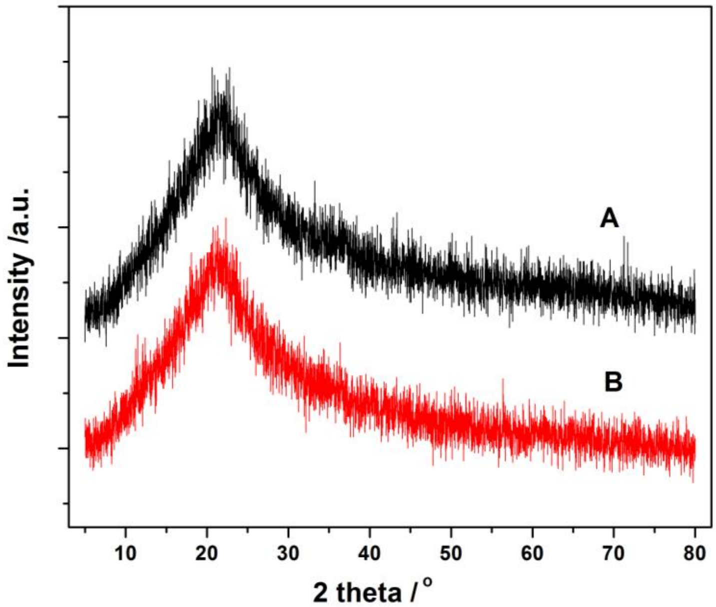

Fig. 3 XRD patterns of glass binder (A) and the glass binder heat-treating at 840 °C for 10 h (B)

The main kind of binder for current domestic production of corundum grinding wheel is ceramic binder. Their firing temperature is above 1200 °C and firing time is up to 60 h even more than 90 h. With China's increasingly stringent energy saving requirements, the high-energy consumption of production has been clearly inconsistent with the current actual requirements. In the present work, we develop a novel low temperature sintering glass binder for corundum wheel, and the sintering temperature is only 840 °C and the total sintering time is no more than 20 h. Obviously, The energy savings of this low temperature binder for the preparation of corundum wheel are significant. To further test the performance of low temperature glass binders, we prepared an experimental sample of corundum wheel (Fig.4A). The test results show that the performance of the grinding wheel has reached the same performance with high temperature sintering products. Fig. 4B shows the sintered batch grinding wheel product with low-temperature glass binder.

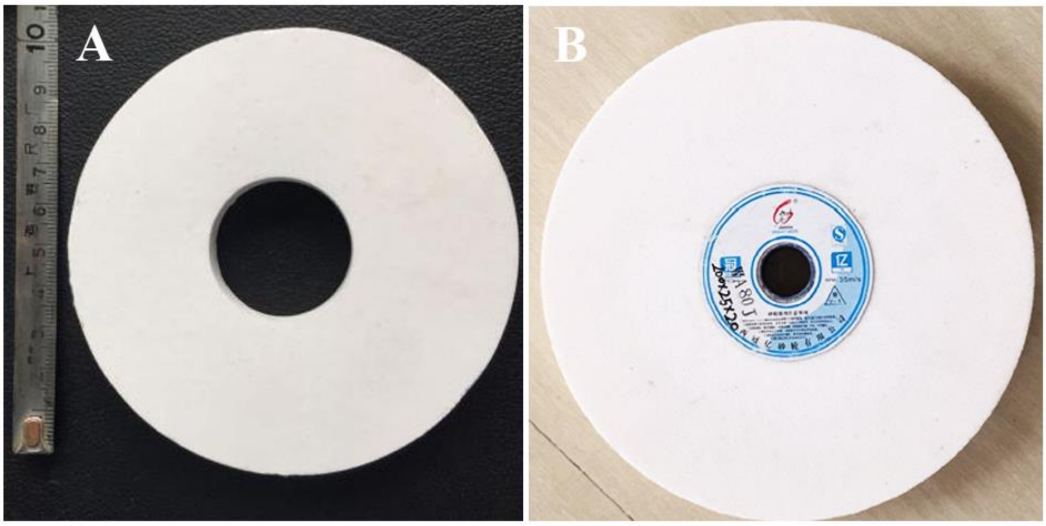

Fig. 4 the photos of the grinding wheel prepared at laboratory (A) and factory (B)

4. Conclusion

The glass powder in K_2O-Na_2O-B_2O_3-Al_2O_3-SiO_2 system has a flow temperature of 853 °C and excellent thermal stability under 840 °C, which is an idea binder for corundum wheel sintered under low temperature. The performance of the grinding wheels prepared under the sintering condition of 840 °C for 10 h is consistent with that of the grinding wheels prepared by the traditional ceramic bonding agent at 1270 °C for more than 60 h. Huge energy savings are expected to bring significant benefits to the industrial production of corundum wheel.

Acknowledgements

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