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Preparation, Characterization and Performance of Conch Ceramics Added With Shell

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Abstract. The conch ceramics bodies with different ratios were prepared by compression moulding technology using shell, kaolin, and calcium oxide etc. as the raw materials, and then calcined at the high temperature to obtain the conch ceramics. The effects of raw material ratios and calcination temperatures on the performance of conch ceramics were investigated by rotational viscometer, vernier caliper, digital display whiteness meter, thermal analyzer, and Fourier transform infrared spectrometer(FT-IR). The results indicated that the viscosity, line shrinkage rate, and whiteness of the conch ceramics were 1.29 Pa·s, 17.9%, and 54.1%, respectively, when the content of the shell powder was 20 wt% and kaolin was 65 wt%. The density of the conch ceramics was the largest (3.8 g/cm^3) when calcination temperature was 1200 °C. The results of FT-IR spectrum showed that the addition of the shell powders changed the structure of the ceramic body, which improved the performance of the conch ceramics.

1. Introduction

"21st century is an ocean century". Guangdong province has a huge advantage in the development of Marine economy due to its special geographical location, so the gross output value for marine economy of Guangdong province has ranked the first in 11 coastal areas for 13 consecutive years [1]. The production and processing of shellfishes plays an important role in Guangdong marine fishery with a large amount of solid wastes calls "shell" generated every year [2]. Nowadays, the exploitation of these shells is unreasonable, most of which are used as building materials, building backfill materials or even disposed in landfills directly, which not only wastes the precious resources of shells, but also takes up the plenty of land resources [3].

There are two important national ceramic production bases in Guangdong province–Chaozhou and Foshan, both of them have a pivotal position in Chinese ceramic

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industry [4,5]. The key of ceramics is raw materials, including clay and kaolin [6], but due to the long history of ceramics in Chaozhou and Foshan, resulting in the shortage of clay, so some ceramic enterprises need to carry into clay from other places, which seriously restricts the development of ceramic enterprises. Therefore, it is urgent to seek new ceramic materials, but at present there are only several types of ceramics in the world, one of which is bone china. Bone china was prepared by add bone powders into the traditional ceramic raw materials, belongs to high-grade ceramics. Although bone china exhibits an outstanding appearance and performance, it requires a large amount of bone powders, which costs a lot [7]. Compared to the bone china, conch ceramics also is high-grade porcelain, but exhibiting a higher performance and lower price. Conch ceramics was prepared by adding a certain amount of shells which via special craft processing into the traditional ceramic raw materials, and then biscuit firing and glaze firing for twice. Shell powders are rich in the composition of pearl, thus conch ceramics has the luster and brightness of which ordinary porcelain lack. However, the report for conch ceramics prepared using shell powder as raw material is seldom at present.

Using kaolin, shell powder, calcium oxide, polyacrylamide and polyethylene glycol as raw materials, the conch ceramics was prepared through four steps of preparing shell powder, mixing raw material, blank forming and sintering in this paper. The influence of the content of shell powder on the viscosity, line shrinkage rate, and whiteness, respectively and the influence of calcination temperature on the density of the conch ceramics were investigated, besides, the structure and morphology of the conch ceramics was characterized by FT-IR.

2. Experimental

2.1Materials preparation

2.2Shell powders preparation

The shells used in the experiment were collected from Chaozhou. The shells were cleaned firstly, and then dried at 110 °C for 10 h in an electrothermal blowing drying oven, sifted through 100 mesh sieve after grinding and added into the beaker with 12% NaOH. After reacting in water bath pot at 70 °C for 5 h, the mixture was washed with distilled water to be neutral, dried at 110 °C for 10 h in the electrothermal blowing drying oven after vacuum filtering, and then heated at 800 °C for 2 h in a muffle furnace to obtain the final shell powders.

2.3Raw materials mixture

Using kaolin as fundamental raw material, shell powders as pore-forming agent, calcium oxide as fluxing agent, polyacrylamide as stable foam agent and polyethylene glycol as binder, the experimental formula of the conch ceramics was according to the proportion in table 1, weighing the dry raw materials and adding solid total mass about 25% of water to mix, and then stirring with the speed of 1500 r/min in a magnetic stirring apparatus at room temperature for 1 h. The suspensions of the above samples were put into an ultrasonic cleaning machine to clean for 1 h in order to disperse the ceramic ingredients evenly.

2.4Forming and sintering of ceramic body

The ceramic slurries were formed by compression moulding technology, and the ceramic slurries with different contents of shell powders were respectively compressed into ceramic bodies by a tablet press, and the ceramic bodies were dried at 180 °C for 3 h in the electrothermal blowing drying oven to obtain the ceramic bodies with certain strength. The ceramic bodies were slowly dried at 40 °C in the electrothermal blowing drying oven in order to restrict their moisture content below 2%, and then the ceramic bodies were calcined in the muffle furnace for 1.5 h, using the method of natural cooling to obtain the conch ceramics.

2.5Experimental methods

Five ceramic bodies with the optimal proportion were calcined in the muffle furnace for 1.5 h under the calcination temperature of 900, 1000, 1100, 1200, and 1300 °C; respectively. The performance of the conch ceramics which prepared under the condition of the optimal proportion and the optimum calcination temperature was characterized by viscosity, line shrinkage rate, whiteness, density and FT-IR.

TABLE 1 EXPERIMENTAL FORMULA OF CONCH CERAMICS (WT%)

Material / Series	Shell powder	Kaolin	Calcium oxide	Polyacrylamide	Polyethylene glycol
A	0	85	5	5	5
B	5	80	5	5	5
C	10	75	5	5	5
D	15	70	5	5	5
E	20	65	5	5	5
F	25	60	5	5	5
G	30	55	5	5	5
H	35	50	5	5	5
I	40	45	5	5	5

2.6Conch ceramics characterization

The viscosity of the slurry was measured using digital rotational viscometer(NDJ-5s, LunJie, Shanghai); The line shrinkage rate of the ceramic body before and after sintering was observed using vernier caliper; The whiteness of the conch ceramics sample was determined using digital whiteness meter (WSB, Weida, Dongguan); The density of the conch ceramics sample after calcination was determined by Archimedes drainage method; The functional group and the change of the chemical composition of the conch ceramics sample were analyzed by Fourier Transform Infrared Spectrometer (FT-IR, 8400S, Shimadzu, Japan).

3. Results and Discussion

3.1Influence of shell powder content

The effect of shell powder content on the viscosity, line shrinkage rate, and whiteness for the conch ceramics was shown in Fig.1. As shown in Fig.1 (a), the viscosity of ceramic slurry increased with the decrease of the shell powder content, and the liquidity of the slurry was poor due to its high viscosity, retarding the absorption slurry rate, which is not conducive to the diffusion of moisture in the ceramic body, therefore, the pouring time for product molding was increased and the ceramic body was not easy to form. From Fig.1 (b), the line shrinkage rate of the conch ceramics was the highest when the shell powder was 20 wt% namely E series. Under the condition of the same temperature, pressure and slurry, the density increased with the increase of the line shrinkage rate, and the ceramic body became smooth. From Fig.1 (c), the whiteness of C series was the highest, and E series ranked second, while A series was the minimum. When the shell powder content was low, the whiteness increased with the increase of the shell powder content. When the shell powder content exceeded 10 wt%, the whiteness of the conch ceramics exhibited a tendency of decrease. Following comprehensive consideration, the shell powder content of 20 wt% namely E series was chosen as the optimal proportion, and the viscosity, line shrinkage rate, and whiteness were 1.29 Pa·s, 17.9%, and 54.1%, respectively.

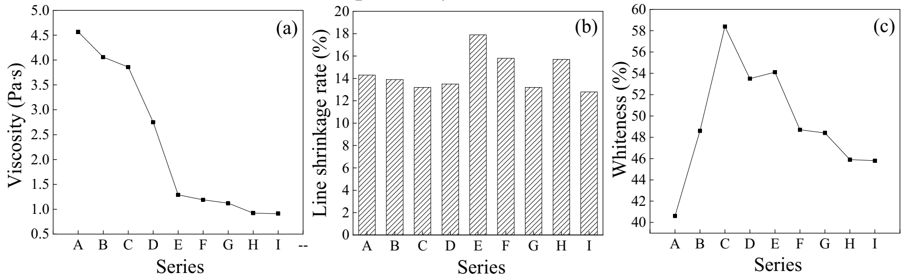

Fig. 1. Effect of shell powder content on the viscosity, line shrinkage rate, and whiteness for the conch ceramics

3.2Influence of calcination temperature

The influence of calcination temperature on the density of the conch ceramics was shown in Fig.2. From Fig.2, when the calcination temperature increased from 900 °C to 1200 °C, the density of the ceramic body increased gradually, the reason of which was that the interior particles of the ceramic body have not been compacted, resulting in a large porosity under the low calcination temperature, so the density of ceramic body increased with the increase of calcination temperature. However, when calcination temperature exceeded 1200 °C, individual particles growed abnormally due to the high temperature, and pores formed between particles, which eventually led to the decrease of the density. Therefore, 1200 °C was the optimum calcination temperature, and the conch ceramics has the highest density, reaching at 3.8 g/cm^3.

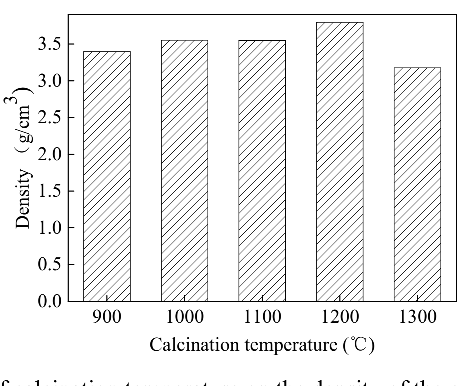

Fig. 2. Influence of calcination temperature on the density of the conch ceramics

3.3FT-IR analysis

As shown in Fig.3, the ceramic bodies with different shell powder contents displayed similar spectrum. The band at 3653 cm^{-1} was assigned to the stretching vibration peak of O–H in the external of the kaolin octahedral coordination, and the band at 1460 cm^{-1} could be ascribed to the asymmetric stretching vibration peak of CO_3^{2-}. Since there were no any shell powder in A series and the main component of shell was calcium carbonate, so there were no any asymmetric stretching vibration peak of CO_3^{2-} in A series. After calcinied at 1200 °C, there were three characteristic bands of metakaolin in medium low frequency area: the band at 1034 cm^{-1} corresponded to the stretching vibration of Si-O while the bands at 694 cm^{-1} and 820 cm^{-1} could be assigned to the bending vibration of Si-O-Al, and the band at 467 cm^{-1} was attributed to the bending vibration of Si-O. The band at 914 cm^{-1} was related to the bending vibration of Al-OH in the structure of kaolin. This suggested that after calcinied at 1200 °C, the $[AlO6]^{9-}$ structure of kaolin was greatly damaged, causing most of kaolin transformed into metakaolin. From A to I series, the intensity of peak gradually decreased between 400 and 1100 cm^{-1}, finally even disappeared, which was because the shell powder and water mixed with kaolin caused the formation of hydrogen bonds in the position of carbonate and hydroxyl decreased the number of bonds such as the pure Si-O and Al-O bonds, so the electron pair position occurred deviation, affecting the intensity of the peaks.

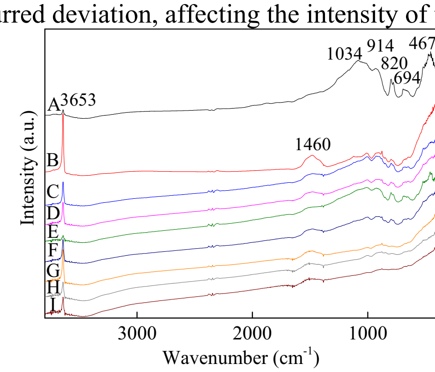

Fig. 3. FT-IR spectrum of the ceramic bodies with different shell powder contents

4. Conclusions

(1) The influence of the material ratio on the viscosity, shrinking rate, and whiteness of the conch ceramics was investigated by changing the content of shell powder in slurry. The results showed that when the content of the shell powder was 20 wt%, the performance of the conch ceramics was optimal, and the viscosity, line shrinkage rate, and whiteness were 1.29 Pa·s, 17.9%, and 54.1%, respectively.

(2) By investigating the influence of calcination temperature on the density of the conch ceramics, it was discovered that when calcination temperature increased from 900°C to 1300°C, the density of the conch ceramics presented the trends of firstly increased and then decreased, therefore, 1200 °C was the most optimum calcination temperature, and the conch ceramics has the highest density, reaching at 3.8 g/cm^3.

(3) From the results of FT-IR, most of the kaolinite transformed into metakaolin under the calcination temperature of 1200 °C, and the shell powder and water mixed with kaolin caused the formation of hydrogen bonds in the position of carbonate and hydroxyl decreased the number of bonds such as the pure Si-O and Al-O bonds, so the electron pair position occurred deviation, improving its performance.

5. Acknowledgments

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