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In Situ Solidification Formation of the Architectural Ceramics Body with Full Barren Materials

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Abstract. The traditional architectural ceramic body is mainly molded by compression forming process with dry power. The study introduced the starch into the body formula and the feasibility and correlate technological means of the situ solidification forming of fly ash architectural ceramics body with full barren materials were discussed. The body with full barren materials has a low green strength which is less than 1MPa by the traditional compression forming with dry power. But it could be improved greatly by optimizing the kind and amount of starch and the heat holding technologies in the forming process. The research showed that the body's green strength is higher by introducing modified potato starch. The sintered body's porosity and water absorption will be increased and lower flexural strength will be obtained by more starch. The body's properties show the best when the amount of the starch reached 4wt% and the holding time for demoulding is 70min under the holding temperature what is 80°C. Under that molding condition, the green strength reached 3.61MPa, the flexural strength and water absorption of the sintered body reached 49.01MPa and 0.17% separately.

Introduction

China has the maximum fly ash emission in the world what reached 450,000,000 tons just in 2010. Because of the enormous environment pressure, the recycling development and utilization of the fly ash was being the key study in the ceramic field [1-4]. Also in the general architectural ceramic preparation, the main superior natural ceramic raw materials such as clay, china stone, quartz and black clay are increasingly shorted. So, take the industrial solid waste fly ash as the main materials to instead the traditional natural materials have the important significance on the energy conservation and emission reduction.

But, the green strength was no more than 0.28Mpa when the volume of the fly ash reached no less than 85wt% what can't satisfied with the large-scale production demand that the green dry strength should not less than 1Mpa[5]. Although add the mineral sticky raw materials into the body can enhance the green strength, the use ratio of the waste will be decreased. So, the author creatively adopted the colloidal forming technology widely used in the advanced ceramic field [6-8] into the architectural ceramic producing process to enhance the green strength and the relative methods were applied for a relative National Invention Patent [9].

In order to resolve the problems what will happen in preparing the traditional architectural ceramic with the high industrial waste in the formula. The effect of the kinds and amount of starches and the thermal holding system for demoulding body on the green body strength and other technological parameters were discussed in this research.

Experiments

The 80wt% fly ash, 8wt% dolomite, 8wt% feldspar, and 4wt% quartz were taken as the full barren fly-ash architectural basic body formula. And five kind starches which is the tapioca, modified tapioca starch, modified corn starch, starch acetate and modified potato starch were added into the formula separately with different amounts. The materials and starches were mixed with the water uniformly and then the slurry was injected into the non-water-absorbing mould after vacuum degassing. The

mould filled with the slurry was put under a thermal state that has the temperature what is 60-80 °C and the slurry would be solidified by the starch dextrinization. Then, the green body was dried and sintered at the1160°C after demoulding from the mould.

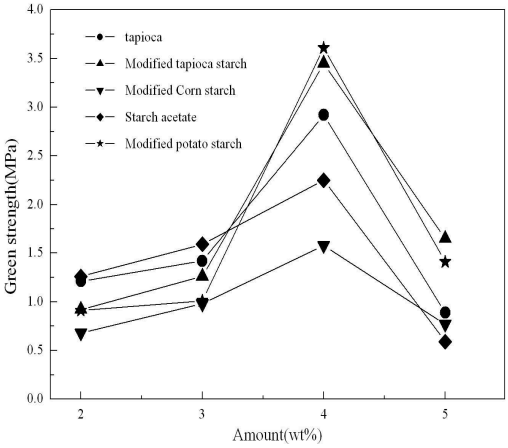


Fig.1 Effect of different starches on the green strength

Results and Discussions

Effect of the kind and amount of starch on body's properties. As the curves showed in Fig.1, the green strength is increased firstly and then reduced when adding starches and it is widely improved to 3.61Mpa when added 4wt% modified potato starch into the basic formula. Modified starch has strong polar groups what could act on the particles in the slurry and make for diffusing the starch molecule. Based on the plentiful hydroxyls, the starch could carry out some chemistry reactions with many other substances [10]. Compared with the other starches, the potato starch contains hydrophilic phosphate groups what not only can enhance the affinity between starch and water and improve the jelly strength, but also it could interact with the balance iron such as K^+, Ca^{2+}, Na^+, Mg^{2+} to promote starch's water swelling.

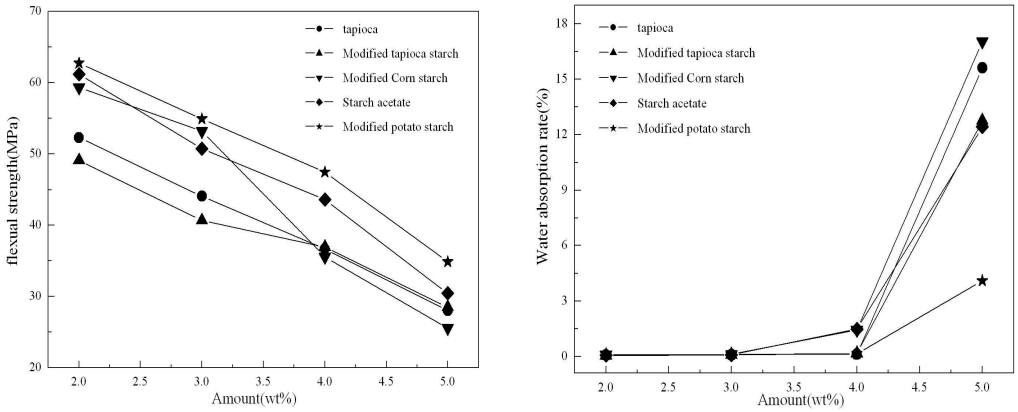


Fig.2 Effect of different starches on the flexural strength and water absorption of body sintered at 1160°C

Meanwhile, the flexural strength of products will be decreasing and the water absorption will be enlarging with adding the starch (showed in Fig.2). Probably, the reason is that the water what is absorbed in the heating solidified process be a part of the structure of the green body. And in the sintering process, the solidified starch and water were burned out and the porosity structure was forming (showed in Fig.3). The size of the pore became bigger when increase the amount of the starch what could be seen in the Fig.4. The big pore will reduce the loading cross sectional area obviously, so bigger pore will make the base material undertaken larger stress and the strength declined. For this reason, the value of flexural strength turns the opposite changes to the amount of the starch. At the meantime, the water absorption of product is lower than 0.5% when the amount of starch no more 4 %(showed in Fig.2). So, the performance of the product turns preferably when the additional amount of starch changed from 2% to 4% in conclusion.

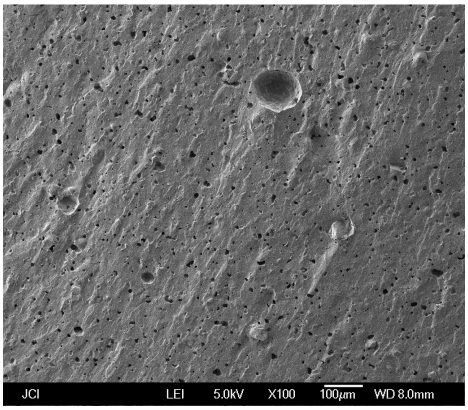
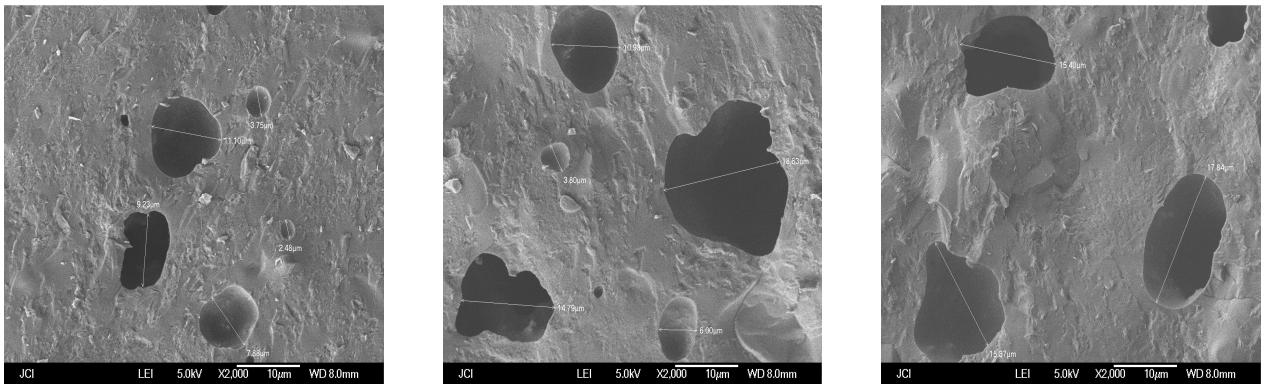


Fig.3 The scanning micrograph of the sintered body



2% modified potato starch 4% modified potato starch 5% modified potato starch

Fig.4 SEM micrographs of sintered bodies with different amount of the modified potato starch

Table 1 The body's demoulding state in the different thermal holding system

Demoulding State	Liquid	Nearly solidified and can't demould	Nearly solidified and can demould partly	Can nearly demould	Can demould completely
50°C	< 110min	120-130min	140min	150min	160min
60°C	< 60min	70-80min	90min	100min	110min
70°C	< 30min	40-50min	60min	70min	80min
80°C	< 20min	30-40min	50min	60min	70min

Effect of the thermal holding system in the molding process on the demould performance of the green body. The basic formula slurry added 4% modified potato starch was stayed at 50°C, 60°C, 70°C, 80°C for gelatinization separately. And the effect of different holding temperatures and holding times on the demould performances of the green body were discussed. The results showed the body's demoulding state in the different thermal holding system. The lower holding temperature, the longer solidified time would be carried for demoulding(showed inTable.1). The thick arrangement of the molecules from the surface and interior of the modified potato starch granular are destroyed in the starch modified process. So, the water molecular enters into the interior of the starch granular easily and also the starch molecular is likely discharge from it [12]. The appropriate gelatinization temperature and time could boost the water molecular swell up the starch and make the starch granular dissolved sufficiently. The properties of the product demoulded at different holding temperature were characterized in Fig.5 and Fig.6.

The green strength and flexural strength of the sintered body are increased and the water absorption is reduced with elevating the holding temperature. It reaches the best what is 3.61MPa, 49.01MPa and 0.17% separately when the holding temperature reaches 80°C. The modified potato starch has high swelling capacity and water absorbing capacity what could make the starch molecular chain stretched to set up a gel net. The gel net coat the ceramic particle's to make the particle sticks to each other. And the reaction will be more effective under the appropriate holding system to bring out the in situ solidification forming.

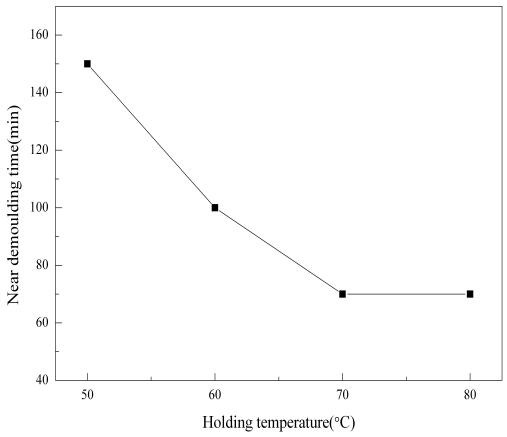


Fig.5 Effect of different holding temperatures on the demoulding time

Conclusions

The study innovatively adopted in situ solidification wet casting moulding with full barren materials with high

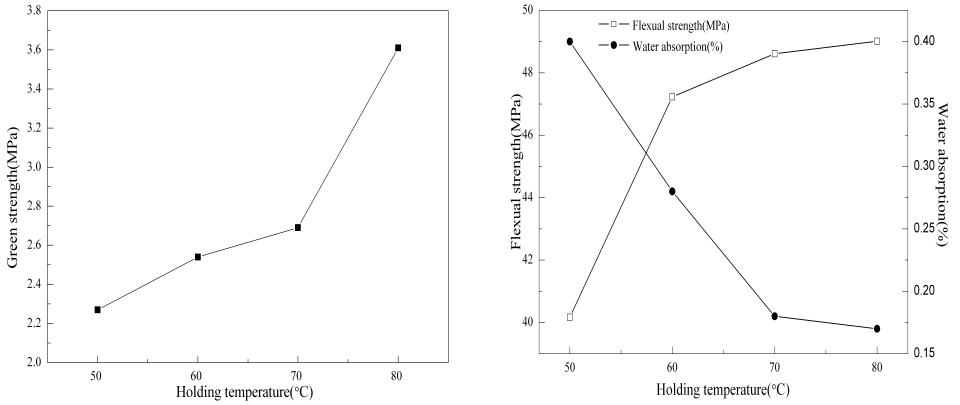


Fig.6 Effect of different holding temperatures on the body's green strength, the flexural strength and water absorption of the sintered samples

volume fly ash for preparing architectural ceramic. The high green strength which is 3.61 MPa was got by optimizing the kind of starches and preparation technology to meet the large-scale production demand. This forming technology could solve the key problem what is that the amount of the fly ash in the formula is limit to the green strength under the traditional dry pressing craft. So, the relative studies will availably expand the application prospect of industrial waste in architectural ceramic field. The researches were showed as following: (1) The kind and amount of starch play an obvious role on the product's green strength and other sintering properties. The product added modified potato starch in the formula could get the best performances than other starches. (2) The size of the pore became bigger, the water absorption rate will be increased and the flexural strength will be reduced when increase the amount of the starch in the formula. And the best amount of the starch is 4wt%. (3) When the holding temperature goes up, the time for demoulding is shorten, the green strength and flexural strength of the body are increased and the water absorption is reduced. The properties reach the best when the holding temperature goes up to 80°C and the time for completely demoulding only need for 70min.

Acknowledgements

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