Research on the Sustainable Utilization of Ceramic Waste under the Green Development Model

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Abstract: China is a big ceramic country, and the production of ceramics has been the first in the world. With the development of the ceramic industry, there are also more and more waste materials. Such a large amount of ceramic waste is not a simple landfill that can solve the problem. Through the analysis of the current situation of solid waste in our ceramic industry, we see that the modern decoration and ceramic raw material regeneration technology to the life cycle of ceramic product design and arrangement make the resources and energy most effectively consumption configuration, so as to achieve the purpose of ceramic waste reduction, recycling, harmless, make ceramic industry production on the road of sustainable development.

1. Introduction

Under the social background of vigorously developing a "low carbon economy," the ceramic industry, with high energy consumption, high pollution, and a high waste rate, has also attracted wide attention. With the rapid development of the ceramic industry, ceramic industrial waste is increasing day by day. According to statistics, Foshan ceramic production area alone produces about 4 million tons of various ceramic waste every year, and the annual output of national ceramic waste is estimated to be about 10 million tons. Although it is difficult to weather after thousands of years, the cost of recycling waste ceramics is greater than the cost of buying clay production. Therefore, most ceramic enterprises are not willing to recycle the waste ceramics [2]. At present, the waste of China's ceramic industry is still a simple way of accumulation and landfill, resulting in a huge waste of land, mineral resources, and environmental pollution, hindering the sustainable development of China's ceramic industry. But suppose ceramic waste recycling is designed and reconstructed. In that case, ceramic enterprises can reduce waste emissions and even achieve zero emissions, with high environmental and economic benefits. Therefore, the study of how to sustain the use of ceramic waste is an important topic.

2. Classification of ceramic waste materials

Ceramic waste can be divided into raw and burned waste, glazed waste, and unglazed waste. Raw waste mainly comes from forming, drying, glazing, and handling processes. The waste can be in their respective enterprise internal recycling but in part of the daily ceramics or sanitary ceramics production process because the glaze composition contains heavy metals or coloring elements, so the glazed waste or glaze after glazed waste cannot be reused before the treatment method is with the burned waste as a building or road filling soil. Burned waste from the kiln burned after the inspection of unqualified products, the quality of these products because of very Subtle flaws and become defective products, and enterprises are generally difficult to reuse.

3. Pollution and treatment status of ceramic waste

With the rapid development of the social economy and the ceramic industry, the ceramic industry waste is increasing day by day, which not only causes great pressure on the urban environment but also limits the development of the urban economy and the sustainable development of the ceramic industry. A large amount of waste porcelain littering resulting on both sides of the road is the bank, river, and other ceramic garbage flooding, seriously polluting the environment. Because the waste cannot be degraded, landfill treatment needs to occupy a large amount of land, and ceramic production needs to consume a lot of raw mineral materials. Mining raw materials will cause a large amount of farmland and forest vegetation damage, and mineral resources have been increasingly exhausted. So the treatment and utilization of ceramic industrial waste are very important.

At present, developed countries attach great importance to the treatment and recycling of ceramic

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industrial waste. Some tile factories in the UK recycle up to 40% of their ceramic waste. Due to its lack of resources, Japan attaches great importance to the treatment of ceramic industrial waste and has a strong sense of environmental protection. It insists on the processing and recycling of ceramic waste. The research is 10 to 20 years earlier than in China, and the technology is mature. Some large multinational companies, such as INAX Co., Ltd. in Japan, have already started the large-scale recycling of ceramic waste, whose waste utilization rate is almost 100%. And the domestic ceramic industry in recent years. The rapid development, accompanied by the increase of ceramic industrial waste, causes great pressure on the urban environment and limits the sustainable urban development of the social economy and ceramic industry, so the reasonable treatment and comprehensive utilization of ceramic industrial waste have become the necessary way[1,2]. At present, the treatment and utilization of ceramic industrial waste in China is relatively low, and they generally choose stacking and landfill disposal. Not only cause a large amount of waste to occupy farmland and the ocean but also causes secondary pollution of water and air. Therefore, our country must attach great importance to the recycling and utilization of waste materials in ceramic production, raise it to the height of environmental materials to study and use, and mention High to the national green environmental protection height to pay attention to and solve.

Table 1. The output and treatment of ceramic waste from some Italian manufacturers and China

Type of ceramic waste	Italian		China	
	Output/ t	Treatment/ t	Output/ t	Treatment/ t
Pottery	170675	178174	457630	433530
Porcelain	109960	116164	655970	625230
Mud	30853	30462	81320	3920
Lime	2298	2203	0	0
Total	313786	327003	1194920	1062680

The treatment and utilization degree of ceramic industrial waste in China is relatively low, resulting in a large number of waste residues occupying farmland so that the water and air are polluted. Especially after nearly 20 years of rapid development, the ceramic industry, with the increase in production, the number of waste is more and, such a large number of ceramic waste is no longer simply landfill can solve, and with the increasing economic development and social progress, the environment has become the focus of people's attention. The accumulation of ceramic waste occupies the land, affecting the dust content of the local air, and the landfill of ceramic waste consumes manpower and material resources and also pollutes the underground water sources. How to turn waste into treasure, reduce pollution, and achieve synthesis Utilization, waste into resources, cherish resources, and save mineral resources have become a top priority[3].

4. Materials and Methods

4.1. Clear glaze is prepared from ceramic waste

The poor quality of the glaze of some ceramic products is a common problem in China's daily porcelain industry. Around how to improve the high appearance and quality level of glaze products, many ceramic science and technology authors have carried out a lot of effective work. According to the production characteristics of a factory, the daily porcelain products glaze quality, production technology, and technical research in the raw materials of the product plus some waste porcelain powder, a more satisfactory transparent glaze formula is successfully developed, product glaze bright, smooth, large products obvious glaze and not obvious glaze defects significantly reduced, has achieved more successful effect.

Waste porcelain powder instead of feldspar and quartz[5].

Use waste porcelain powder to replace feldspar and quartz and reduce the original formula of feldspar and quartz raw materials. List of raw materials and their chemical composition. (Table 2.).

Table 2. The chemical composition of the raw material (%)

Name	SiO_2	Al_2O_3	K_2O	Na_2O	Fe_2O_3	CaO	MgO	TiO_2
Ceramic waste powder	69.27	22.99	2.44	1.12	0.32	1.34	1.17	0.10
Quartz	99.82	—	—	—	—	—	—	—
Feldspar	65.54	18.02	10.05	4.75	0.11	0.32	0.03	0.01
Light calcium carbonate	0.36	1.08	0.05	0.22	0.01	53.25	1.14	0.05
Talcum	64.13	1.07	—	—	0.21	2.36	31.91	0.31
Longyan	72.68	17.36	1.30	1.00	0.23	0.18	0.41	0.08

4.2. Analysis of the reasons for the poor glaze quality

The main defects resulting in poor glaze quality are glaze pinhole, glaze bubble, the glaze is not dry (depression, water ripples), etc., especially the irregular pinhole, the production quality is difficult to control. Due to the more organic matter and gas in the glaze or the blank body, the high-temperature viscosity of the glaze is large. The gas produced by the high temperature of the organic matter is difficult to discharge, coupled with the low melting temperature of the glaze. The glaze is particularly easy to form pinholes and glaze bubbles, which has a certain impact on the gloss of the glaze. Therefore, to improve the first-grade yield of products, the key is to improve the quality of the glaze of ceramic products, especially to reduce the glaze pinhole, glaze bubbles, and other defects. In addition, the glaze gloss of the product is also related to the refractive index of the glaze. The refractive index of the glaze is high, and the glaze gloss of the product is high. For this reason, we often add some oxides with a higher refractive index to improve the glaze gloss.

The research focuses on the detailed analysis of the glaze formula and its preparation process, glaze application, firing, and other aspects, and determines that the main reasons for the above product glaze defects are large high-temperature viscosity, low initial melting temperature, narrow firing temperature range, and poor combination of blank glaze.

4.3. Development of glaze material

Glaze formula development, according to the analysis of the cause of poor glaze quality, the development of a new glaze formula focus on reducing glaze viscosity at high temperature, improving glaze melt temperature, and widening the glaze firing temperature fan. With waste porcelain powder, lightweight calcium carbonate, feldspar, and zinc oxide as the main raw material, with a certain amount of quartz, talc powder, barium carbonate, etc., at the same time to ensure the performance of the glaze, using a small amount of dragon rock to adjust. The use scope of various raw materials is as follows: waste porcelain powder 35%6~45%, lightweight calcium carbonate 15%~20%, feldspar 15%~20%, quartz 5%~10%, zinc oxide 3%~66%, talc powder 2%~5%, dragon rock soil 2%~3%%, barium carbonate 2% less.

After repeated tests, the transparent glaze formula with a good firing temperature range of 1220~1240 ℃ and the blank body was successfully developed. The developed product glaze is smooth and soft, with few unequal defects in pinholes and glaze surfaces. The chemical composition of the glaze is shown in Table 3.

Table 3. Chemical composition of glaze (wt%)

Name	SiO_2	AL_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	BaO	ZnO
Content	65.13	12.59	0.14	9.32	2.04	4.31	1.65	1.55	3.27

The glaze preparation process is also a very important link. The waste porcelain powder is the broken porcelain of daily porcelain, which must be strictly selected, washed, and crushed when used. Zinc oxide and talc powder were calcined at 1260~1310 ℃ before use. Material: Ball: water = 1:2:0.7. Fineness of ball abrasive: square hole sieve allowance 0.01%~0.03%. Glaze sieve three times: 180,200,220 sieves. Secondary iron removal. Tale corruption period: 1~2d. The glaze is done with a density of 1.35 to 1.45°Bé. Before firing, the glaze products need to be dried in the oxidation atmosphere in the daily ceramic tunnel kiln. Temperature levels ranged from 1220 to 1240 ℃. Good product performance: thermal stability: 220 to 20 ℃ heat exchange once no burst; whiteness: 70%; glaze hardness: metal knife, fork cut without marks; Jersey: meet the standard requirements.

5. Results & Discussion

5.1. The role of waste porcelain powder and its various components

The waste porcelain pieces are fired at high temperatures, and the physical and chemical reaction of each component is basically completed. The gas content is very small, so after the appropriate amount of waste porcelain powder is in the glaze, the gas content in the glaze is greatly reduced, thus reducing the defects of the glaze pinhole and glaze bubble. This effectively prevents the glaze from adsorbing more free carbon during the low temperature and heavy reduction phases. On the contrary, If the free carbon is reoxidized to gas during the high-temperature phase, the glaze will produce more pinholes and glaze bubbles, so the appropriate amount of waste porcelain powder in the glaze, the stomatal rate in the glaze layer is greatly reduced. This can prevent the adsorption of free carbon, thus reducing the production of defects such as glaze pinholes and glaze bubbles. Also, mention accordingly that High glaze layer density and glaze reflectivity have a positive effect on improving glaze gloss[4]. The reaction between each component of waste porcelain powder is more thorough, and its activity is poor, so the reaction of waste porcelain powder and other materials is relatively slow, thus improving the initial melting temperature of glaze, which is conducive to the smooth elimination of the gas produced by the physical and chemical reaction in the blank and glaze, so as to reduce the defects such as glaze pinhole and glaze bubble, and broaden the firing temperature range of glaze.

In the development process of this glaze, the influence of waste porcelain powder on the glaze quality is very important. The formula attracts about 40% of the waste porcelain powder to expand the melting range of

the glaze, improve the adaptability of the glaze and the glaze hardness, gloss, and mechanical strength of the product. Waste porcelain powder contains a large amount of glass but also limestone, residual quartz, and other crystal phases. Because the waste porcelain powder has been at too high a temperature in the porcelain reaction, its chemical activity is significantly reduced. So the chemical action with the basic components in the glaze must be much slower. This can significantly improve the initial melting temperature of the glaze and is conducive to the rapid elimination of the new gas produced by the physical and chemical reaction in the blank and glaze. Thus, reducing the glaze pinhole and glaze Bubble defects effectively improves the glaze quality of the product.

Lightweight calcium carbonate is also very sensitive to the effect of the glaze quality, which is the main attractive source of CaO in the glaze. Due to the effect of CaO in rapidly reducing the glaze viscosity at high temperatures, it is conducive to the rapid elimination of the new gas produced by the billet glaze materialization reaction in the firing process and has a very obvious effect on reducing the glaze inequality defects of the product. Meanwhile, because CaO has a high refractive index, it can effectively improve the glaze gloss of the product[6]. In the development process of this glaze, using light calcium carbonate instead of natural limestone raw material for the high purity and stable quality of calcium of light carbonate is beneficial to ensuring the glaze quality. On the other hand, the lightweight calcium carbonate with large fineness and large activity can promote the melting of the glaze during the firing process and enhance the glaze gloss.

6. Conclusions

Ceramic waste is mainly used in the production of glaze in the production of daily ceramics. Through the research of raw material formula and production process, ceramic waste is successfully used in the production of glaze and has achieved a relatively ideal effect.

The recycling of ceramic waste raw materials has not been really applied in China, but it is only in the experimental research stage. I believe it will be fully applied in the near future, which is the need for sustainable development. Natural and high-quality raw materials are becoming less and less, and the sustainable processing of raw materials will be the only way. Accompanied by the research and development of new raw material production processes and constant reduction the cost, and improved product quality, the ceramic industry into the green, low-carbon, sustainable development track.

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