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Development of a Semi-Wet Process for Ceramic Floor Tile Granule Production

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Abstract. In ceramic tile manufacturing industry, the wet process including wet grinding and spray drying, is widely used for preparing granule. However, due to the high energy consumption for the water evaporation in spray dryer, it has become a major problem in wet process. In recent years, there have been vast amount of researches for developing of dry granulation processes in that granule size distributions cause quality problems in the final products.

In this research, it is aimed to develop a new production system, called as Semi-Wet Process. The new system consists of a horizontal dryer, dry ball mill, separator and an additional high speed mixture. The raw-materials having low humidity are ground to the required fineness in dry size reduction process. The other components of recipe, that are prepared in conventional wet process, are mixed with the dry prepared powder in the mixing slurry tank. The addition of dry powder reduces the water ratio of final suspension. Hence, the natural gas consumption of the water evaporation in spray dryer is reduced substantially.The industrial application of the developed Semi Wet System was carried out in Kaleseramik Factory in Turkey, where 28% reduction on gas consumption has been achieved.

Introduction

Ceramic tiles that are mainly used for floor and floor decoration of buildings have been the predominant products of the world's ceramic industry. The general process of manufacturing ceramic tiles consists of such procedures as preparing the proportioned raw materials into granules. Then, the press forming as-received, granules have a specific water content that is usually 5-7 %, into green tiles that are fired into ceramic tile products [1]. Different preparation processes generally produce ceramic powders with different properties. Currently, the ceramic powders for floor tiles are mainly produced by wet grinding and spray drying [2]. Wet preparation system for floor tiles starts with crushing process, where the raw materials such as feldspar, kaolin, quartz and fired ceramic waste are reduced to size of under 1 cm. The raw materials, that compose the body, are ground by wet ball mills until reaching the 4,5 % sieve residue of 45 µm. In addition, clays are dissolved in a blunger to remove the gang minerals before mixing operation. The prepared slurries are homogenized in a mixing pool with the ordered ratios of each material. After screening and removal of iron impurities, the suspension is pumped to spray dryer [3]. The slurry makes contacts immediately with 400–550 ^{o}C hot air for instantaneous drying into fine granules [4].

The technical command of raw material in wet grinding and the excellent performance of spray-dried powders have led to wide-scale industrial application of the spray drying process in the last 40 years. However, the high energy and water consumption involved in size reduction process and spray drying, in addition to emissions that remains major issues [5]. The prepared ceramic slurry has water content of around 36 %, which is evaporated in spray dryer. Hence, the evaporated water

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content of the ceramic slurry directly affects the natural gas consumption in spray dyer. Especially after drying work, the hot air is cooled down into tail gas with temperatures between 90° C and 130° C. Thus, the air is directly discharged with considerable excess heat energy [6].

A new production system, called as Semi-Wet Process, has been designed to reduce granule production costs. Dry material is ground separately in the dry grinding system and added to the ceramic slurry. Hence, the bulk density is increased with the addition of dry material into the slurry. Therefore, the prepared ceramic slurry has less water content than the original ceramic slurry. This provides less natural gas consumption for dewatering of the slurry. In addition, the production capacity of the spray dryers is increased and the energy consumption is also decreased by the use of developed Semi-Wet System.

Methodology

Material Characterization. The raw materials of kaolin (Kao), feldspar (Feld.), and clay and floor tile waste are used in the production of both monocottura and glazed porcelain floor tiles. The experimental study was performed in Kaleseramik Factory, which is the largest ceramic producer in Turkey. Chemical and mineralogical analyses of the raw materials are shown in Table 1.

Table 1 Chemical and mineralogical analyses of the raw materials

Analysis	Oxide (Mass %)	Feld. 1	Feld. 2	Feld. 3	Feld. 4	Clay 1	Clay 2	Clay 3	Kao. 1	Kao. 2	Tile Waste
Chemical XRF	L.o.I	2,72	1,38	2,03	0,63	7,2	3,73	7,57	6,52	2,27	0,31
	SiO_2	70,33	72,97	67,12	72,09	60,79	78,04	59,29	64,52	75,15	67,68
	Al_2O_3	17,04	15,29	18,79	18,21	25,3	13,45	25,67	22,25	14,1	20,55
	TiO_2	0,3	0,24	0,46	0,19	1,39	1,21	1,05	1,11	0,21	0,76
	Fe_2O_3	2,11	1,12	0,16	0,48	1,68	2,03	2,48	2,59	1,35	1,79
	Na_2O	2,12	2,68	7,99	2,59	0,5	0,46	0,49	0,24	0,83	3,4
	K_2O	4,85	5,83	0,46	4,52	2,14	0,57	2,14	1,67	5,22	2,88
XRD	Qualitative	Quartz Sanidine Kaolinite Albite	Quartz Sanidine Kaolinite Albite Kaolinite	Quartz Albite Muscovite Magnesite	Quartz Microcline Albite Muscovite	Quartz Kaolinite Anatase Calcite	Quartz Kaolinite Illite	Quartz Kaolinite Illite	Quartz Kaolinite Illite Anatase	Quartz Ortoclase Albite Illite Kaolinite	Quartz Mullite Albite

Each material shows different mineralogical structure. Cracked pieces of floor tiles, which were taken from Kaleseramik raw material storage area, were crushed and ground by a dry ball mill under the size of 45 microns sieve. The size distribution of the ground floor tile waste has the fineness of d_{90}=28,81 μm, d_{50}=5,23 μm and d_{10}=0,48 μm.

The Current Wet Process And Developed Semi Wet Process. The experimental study was performed in Kaleseramik floor tile granule preparation factory. Floor tiles (Monocottura) must have a water absorption ratio between 0,5 % and 3,0 % by mass. The water absorption ratio must be less than 0,5 % by mass for the glazed porcelain tiles [7]. The currently used process starts with crushing and screening. The aim is to prepare raw materials, such as siliceous kaolin, feldspar and floor tile wastes, for wet grinding feed down to 0,9 mm particle size. In addition, clays are prepared at a homogenizing process plant. The crushed raw materials and floor tile wastes are transported to wet grinding mills. On the other hand, clay materials are dissolved to remove from impurities in a blunger system. These two slurries are homogenized in a mixing pool at ordered ratio and the bulk density of the final slip is around 1660 g/L for monocottura floor tile. The bulk density for glazed porcelain reaches to 1670 g/L. The mixing ceramic slurry is separated from iron impurities in a wet magnetic separator and sieved on the vibrating screens. The final ceramic slip is pumped to spray dryer, where ceramic granule is produced.

The new production system, termed as Semi-Wet Process, has been developed in order to reduce the natural gas consumption for dewatering of slurry. Fig. 1 shows the flow chart of the both currently used wet process and newly developed semi-wet process.

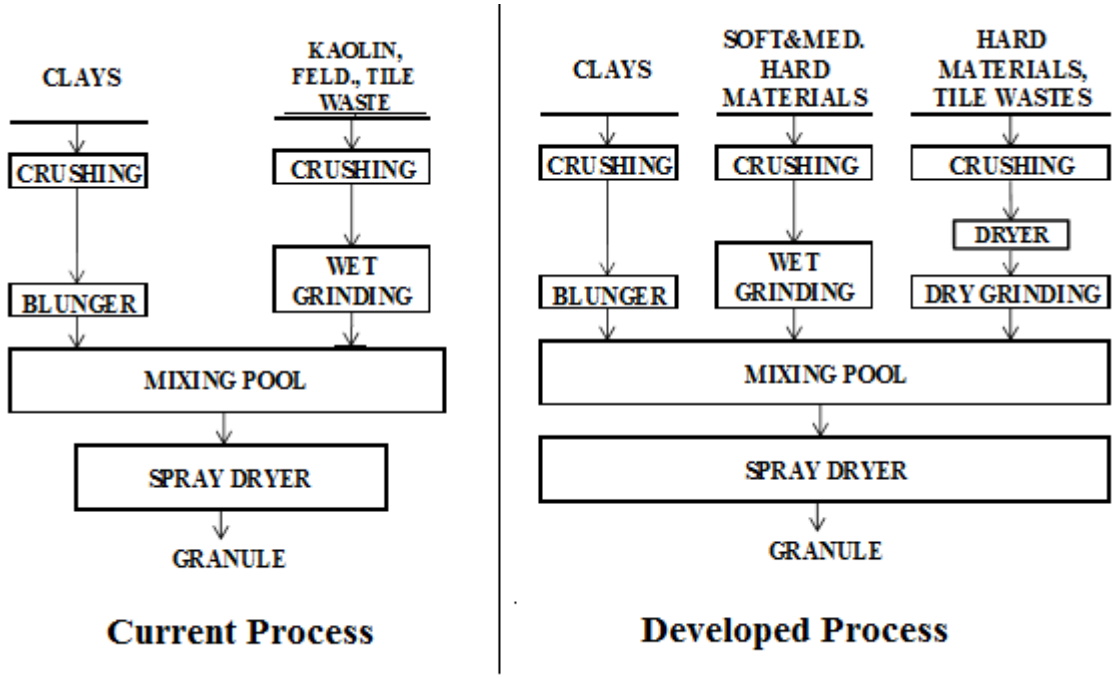


Figure 1 Currently used wet process and newly developed Semi-wet process

As it is indicated in Fig. 1, the hard raw-materials such as feldspar, siliceous kaolin and tile waste that contains humidity less than 10 %, are crushed down to 3 mm particle size by a hammer crusher at the developed process. After crushing process, the materials are dried in a horizontal dryer until reaching to the humidity less than 1,0 %. Then, dry materials are ground by a continuous dry ball mill that is operated together with a rotor type separator till reaching the particle size of 4,5 % residue of 45 μm sieve.

Finally, the dry ground material is added to the mixing pool where clay slurry and other materials are homogenized. The mixing pool is modified to achieve homogenous mixing of wet and dry particles by the addition of a turbo rotary wing. A piston pump is used for efficient pumping of the slurry to spray dryer. The atomizers are spray pressure nozzles, through which slurry is pumped at high pressure. The spray nozzles are mounted on a series of radially arranged lances in the middle of the chamber, the hot air being fed into the top of the chamber [8]. Hence, the bigger nozzles are needed to pump the high density slurry into the chamber. The spray dryer was modified on nozzle parts because of the high bulk density of the slip obtained on new system.

Experimental

The physical properties of raw materials such as moisture content and grindability, were determined. Hence, the dry floor tiles wastes were added to both glazed porcelain and monocottura floor tile body slip compositions by 10, 15 and 20 % by mass. The standard composition and the newly prepared glazed porcelain compositions and monocottura compositions are listed consecutively in Table 2.

Table 2 The recipes of dry ground floor tile waste addition to floor tile body compositions (% mass)

Glazed Porcelain					Monocottura				
Material	**Standard**	**Sample 1**	**Sample 2**	**Sample 3**	**Material**	**Standart**	**Sample 1**	**Sample 2**	**Sample 3**
Feldspar 3	22	19	14	13	Feldspar 1	7,5	7	7	5
Feldspar 4	21	20	23	21	Feldspar 2	32	29	26	24
Kaolin 1	17	16	13	11	Kaolin 2	10	9	11	11
Clay 1	10	10	10	10	Kaolin 1	17,5	18	14	13
Clay 3	25	25	25	25	Clay 2	5	5	5	5
Tile waste	5	-	-	-	Clay 3	22	22	22	22
Dry ground tile waste	-	10	15	20	Tile waste	6	-	-	-
					Dry ground tile waste	-	10	15	20
Total	100	100	100	100	Total	100	100	100	100

The floor tile waste was ground under the size of 45 microns in the dry mil-separator system. It was added by 10, 15 and 20 % into the slurry. Moreover, the slurry were dried to reach the 6 % moisture in the samples. The granules were pressed to having 5 cm diameter samples at 325 kg/cm^2. After that, the samples were dried and then sintered in the conditions of glazed procelain production that is at maximum 1175°C, for 40 minutes and monocottura at 1170°C , for 40 minutes consecutively. The technical properties of the samples such as water absorption and linear shrinkage were measured according to ISO Standarts 10545-2. The color properties of the fired samples were determined using colormeter instrument.

Results and Discussion

The physical properties such as firing shrinkage and water absorbtion of the glazed porcelain (G.Porc.) and monocottura (Monocott.) samples that were prepared by adding 10, 15 and 20 % are given both in Fig. 2.

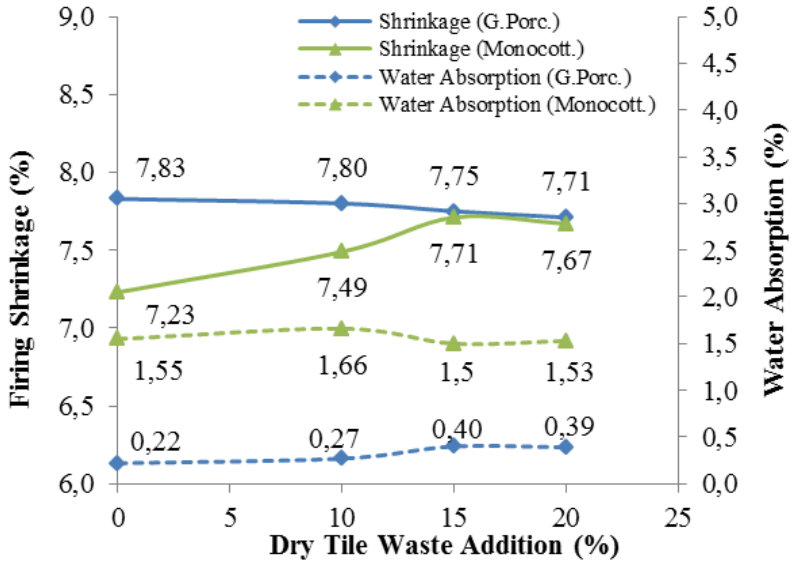


Figure 2 The changes in both water absorption and shrinkage by addition of dry ground floor tile waste

The dry prepared materials such as; floor tile wastes can be added to floor tile and glazed porcelain tile body compositions as much as 20 %. As seen in Fig. 2, the technical properties of the bodies

produced suit well to the desired body composition defined in ISO Standarts 10545-2. The sintered samples also comply with the desired color properties. Fig. 3 shows the natural gas consumption related to density by adding dry ground floor tile waste.

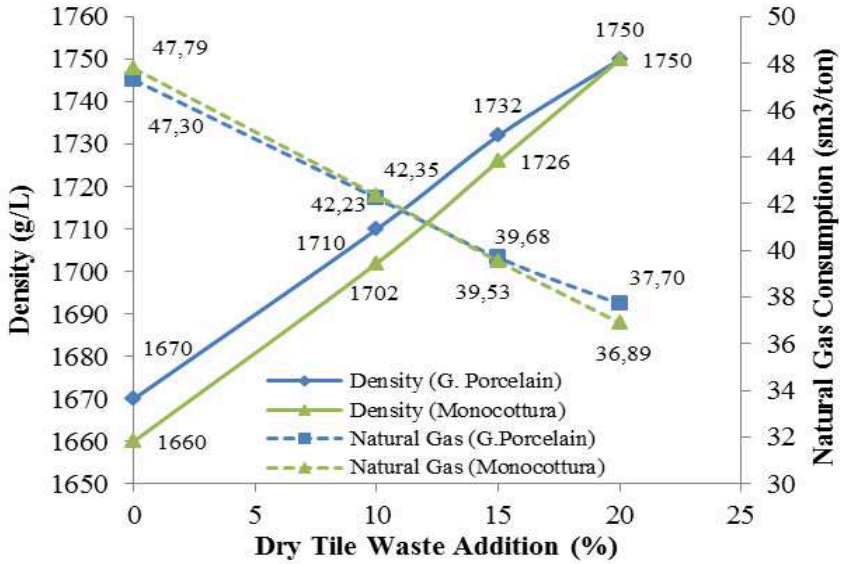


Figure 3 The natural gas consumption related to density by adding dry ground floor tile waste

Figure 3 indicates that density of the ceramic slurry has risen gradually with the addition of dry tile waste into the slurry mix. Hence, natural gas consumption has decreased considerably.

As a result, the density of the monocottura slip rises from 1660 g/l to 1750 g/l, while natural gas consumption decreases from 47,79 sm^3/ton to 36,89 sm^3/ton, whereas the density of glazed porcelain rises from 1670 g/l to 1750 g/l while natural gas consumption decreases from 47,30 sm^3/ton to 37,70 sm^3/ton for glazed porcelain granule production.

Conclusion

The dry prepared floor tile waste powder was added by 20 % to the both monocottura and glazed porcelain body slurry in the mixing tank. Hence, the bulk density of the monocottura slip has risen from 1660 g/l to 1750 g/l, whereas the bulk density of glazed porcelain has risen from 1670 g/l to 1750 g/l.

The use of Semi Wet System can provide savings around 1.962.000 sm^3/year for the monocottura granule production rate of 180.000 ton/year. The savings is around 2.592.000 sm^3/year for the glazed porcelain granule production rate of 270.000 ton/year. It refers to 28 % reduction on gas consumption at the factory where the industrial applications realized.

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