A Preliminary Study: Increasing the Efficiency of Filter Press Process in Art Tile Production

Murat BAYAZIT

Batman Üniversitesi, Güzel Sanatlar Fakültesi, Seramik Bölümü, Batı Raman Yerleşkesi, 72100, BATMAN

m.bayazit@hotmail.com

Abstract

Main materials in production of plastic art tile mud to be used on lathe or mold are clay, kaolin and carbonated materials. Grinding, resting, filter press and vacuum press create the main production stages. The moisture content of mud is very important and the major fact directing this situation is the filter press. In this preliminary work, which aims to increase the production efficiency by reducing the moisture content, a representative recipe created by consideration of other formulas used by the major enterprises in Kütahya (Turkey) and a new recipe including less clay and more non-plastic materials have been prepared for the investigation and reclamation of the moisture contents of the filter press mud cakes. Additionally, drying shrinkage (150^{o}C), firing shrinkage (1050-1080^{o}C), firing color, glaze conformity (910-920^{o}C) and forming performance of the mud (prepared using two recipes) were examined in order to determine the industrial applicability of the new recipe.

Keywords: Art tile, Filter Press, Production Efficiency.

Çini Çamuru Üretiminde Filter Pres Verimliliğinin Arttırılması Üzerine Ön Çalışma

Özet

Torna veya kalıpta işlenecek plastik çini çamuru yapımında kullanılan temel hammaddeler kil, kaolen ve karbonatlı malzemelerdir. Öğütme, dinlendirme, filter pres ve vakum pres işlemleri başlıca üretim aşamalarıdır. Çamur nem içeriği oldukça önemlidir ve bunu etkileyen en önemli unsur da filter prestir. Nem içeriğinin düşürülmesiyle üretim verimliliğinin arttırılmasını amaçlayan bu ön araştırmada filter pres çamur keklerinin nem içeriğinin incelenmesi ve iyileştirilmesi için Kütahya'da çini çamuru üretimi yapan başlıca işletmelerin çamur içeriği dikkate alınarak temsili bir çini çamuru reçetesi ve bu reçeteden daha az kil ve daha fazla özsüz hammadde içeren yeni bir reçete hazırlanmıştır. Ayrıca bu reçetelerle hazırlanan çamurun kuruma küçülmesi (150^{0}C), pişme küçülmesi (1050-1080^{0}C), pişme rengi, sır uyumu (910-920^{o}C) ve işlenebilirliği de gözlemlenerek endüstriyel olarak sürekli üretime uygun olup olmadığı belirlenmiştir.

Anahtar Kelimeler : Çini, Filter Pres, Üretim Verimliliği.

1. Introduction

Art tile ("çini" in Turkish) is one of the most important styles in Turkish art history and is a ceramic material which is produced by double or triple firing also including decorating and glazing [1]. It is a unique ceramic ware thanks to its artistic and visual properties. The beginning of tile art goes back to the ancient times (back to the first half of 3000 BC) in which people began to process soil and produce earthenware pots, and the first examples of art tiles were the architectural decorations [2]. Art tile borders, tiles and mosaics were used as geometric and symmetrical patterns indoors with various shades and combinations of mainly turquoise and cobalt colors [2,3]. After used as an architectural material, art tiles were also used in production of merchandise such as vase, bowl, plate and pitcher with the advantage of its aesthetic features [4]. Glazes used on the art tiles generally include lead in order to increase the brightness and vivacity of the colors and decors. Lead limits the functional use of ware since it takes place as a toxic content in glaze, but on the other hand it positively affects the cost of production by significantly reducing the firing temperature [5]. In this sense, art tiles were usually used for decorative purposes and they had successfully conveyed the cultural and artistic developments between the nations and generations.

Forming, drying, firing, decorating, glazing and glazed firing processes respectively take place in art tile production. Each process requires a specific knowledge and experience. Forming process, which takes the first place in these processes, reveals the basic outline of the product and forms the basis of production. While complex shaped art tiles are formed by casting method, lesser complex shaped products such as plate, bowl, trinket and simple-shaped vase are formed by hand and lathe. Mud used for casting is obtained by wet grinding and sieving of the raw materials. So the most important parameter in that process is the rheological property of the slip. Forming of art tile by plastering mud towards gypsum mold located on a lathe or shaping by hand requires plastic slip which does not include air in it. This plastic slip is prepared mainly by five stages known as raw material selection, grinding, sieving, dewatering of sludge (filter press) and vacuuming of air from the masse [1,2,5,6,7].

During the selection of the raw materials used by the industrial enterprises in Kütahya some visual observations and experimental measurements such as impurity content, determination of color, opening feature, dry and firing shrinkages, fire losses, color specification after firing and water absorption are applied. The first step for choosing the raw materials is the assignation of its color. The color of material can be compared with a same or similar material that is used previously in the plant. Then the impurities such as iron and slag should be established. The third step is to observe behavior of the material in water. This observation is very important especially for the clay and clay minerals. The next step after that is the measurement of dry and firing shrinkage of the material. Dry shrinkage is defined as the length difference between green body and dried body (drying temperature: minimum 80^0C, drying time: minimum 12 hours). Firing shrinkage is the dimensional change after firing (same as drying shrinkage) and measured as the length difference between dried body and fired body (firing temperature of raw material should be equal to that of the ultimate product to get accurate results) [8,9].

The amount of reduction in weight during the firing process indicates the firing losses and gives us information about the firing behavior of the material so that we can classify them. One of the most useful information obtained by firing process is the color of material after firing. Generally, the color of art tiles after firing is yellowish, grey or off-white and it is desired to be white or close to white in order to highlight the decoration figures and their shade. For this purpose, art tile producers use dolomite and chalk. These raw materials are rarely used in other ceramic wares because of their disadvantages (i.e. increasing water absorption). But in traditional art tiles, water absorption is not so important particularly due to its decorative use (except for architectural purpose). In order to measure the water absorption material should be firstly fired at the original firing temperature used in manufacture. After cooled, it should remain in water for minimum twelve hours and then weighed after rinsed. The weight difference between dry and wet materials gives us the amount of absorbed water [10-13].

At the end of these processes appropriate raw materials are brought to a specific particle size by grinding in a ball mill. In order to determine the particle size of the raw materials, % oversize of 100 mesh sieve is calculated. This percentage is the residual weight of the sludge which remains on sieve during the sieving process by using 1 liter of aqueous sample of ground raw materials. It is an important criterion which helps to determine the ratio and efficiency of the grinding. After the milling process if the mud has appropriate % oversize of sieve, it is drained into a stilling pool using a vibrating sieve. In that pool, the mud has a motion with the help of a propeller which moves continuously or intermittently. Thus, problems such as settling and loss of homogenization can be prevented. Next process after stilling pool is the dewatering of mud with filter press. By means of this process the mud loses a large amount of water and begins to become a plastic slip which can be controlled and shaped by hand. Hereby, it also becomes easy to work with slip during the vacuum press process which is the next step in production of the art tile slip [6,7,9,11].

Operation principle of the filter press can roughly be described as the transmission of sludge from stilling pool to the press by the help of a pump. Filter press is composed of steel plates and filtering cloths above these plates. Sludge, sucked by a hydraulic pressure pump, fills in the gaps located among the steel plates with the help of canals crossing through the middle of the plates. After filling all the plates, the compression process starts with filtering cloths. Some important points for filter press are pressure, time, quality of the cloths and number of plates. The properties of the sludge also affect the filter press process (i.e. viscosity, dry matter content, density and % oversize of sieve) [7,14].

2. Material and Methods

As one of the most significant aim of this study is to find a common solution in reducing the moisture content of the slip cakes achieved by filter press and to increase the efficiency in the enterprises, different recipes used by the major producers in Kütahya were determined in order to make a representative recipe for the tile slip. The representative recipe (Recipe No.1) contains %14 clay, %2 bentonite and %42 kaolin in weight. Additionally chalk and dolomite, which are commonly used by almost all the art tile slip producers, take place in the recipe with the ratios of %10 and %14, respectively. Quartz is used with the ratio of %18 in the recipe and has a grain size of ≤63µm. Sludge, obtained by ten milling processes, was accumulated in stilling pool and dewatered in filter press. Then the properties of forming, drying, firing and glazing conformity of the slip were compared with the others sold in market in order to see clearly whether the representative recipe is compatible with the other recipes used in plants. After the production with this recipe the moisture content of the slip cakes (from filter press) was investigated by reducing the percentages of bentonite and clay by %1 and %2, respectively, while increasing the percentages of quartz and dolomite both by %1.5 (Recipe No.2).

The moisture contents of the raw materials were considered in order to determine the precise loading amount of the materials before grinding process (Table 1). Samples were taken from four different sections of a pile of the materials. After 10 gr of samples for each raw material has been prepared separately in laboratory, the samples were dried in dryer at 150 ^{o}C for twelve hours and re-weighed to record the humidity values. Next, materials were installed into the ball mill having a total dry matter of 2000 kg.

Table 1. Moisture content, percentage and the amount of loaded raw materials (totally 2000 kg dry) of new recipe (Recipe No.2).

Raw Material	**% (wt.)**	**Moisture Content (%)**	**Loaded Raw Material (kg)**
Clay-1	12	20.6	302.26
Clay (Bentonite)	1	21.8	25.57
Kaolin-1	30	7.3	647.24
Kaolin-2	6	5.4	126.84
Kaolin-3	6	6.4	128.20
Quartz	19.5	2.2	398.77
Chalk	10	13.4	230.94
Dolomite	15.5	5.3	327.34

Ten wet grinding transactions were carried out for each two recipes (Recipe No.1 and No.2). After the grinding processes for each recipe sludge has been sieved and poured into the stilling pool. The % oversize of 100 mesh sieve, density and dry matter contents of the sludge were calculated by keeping the working time and water content of the mill constant. Then the filter press process was carried out using all of the sludge accumulated in the stilling pool, and the moisture contents of the slip cakes were calculated.

3. Results and Discussion

The first step of the study was the grinding process of the raw materials prepared according to the recipes (No.1 and No.2). After 10 grinding operations applied for both recipes; % oversize of 100 mesh sieve, density and dry matter contents were determined (Table 2 and Table 3). Since the raw materials are generally stocked outside of the enterprises, they can directly be exposed to all environmental and climatic effects. So, the moisture contents of the raw materials may frequently vary especially in rainy and snowy seasons. In the present work, it was seen that the dry matter contents of each grinding process were nearly the same showing that the moisture contents of the raw materials (from the stockpile) were properly calculated. The values of residual weight of the sludge (% oversize of 100 mesh sieve) changed from 1.70 to 2.44 for the recipe no.1 and from 1.80 to 2.32 for the recipe no.2. These ranges proved that the milling processes were successfully carried out with negligible differences in terms of grinding efficiency.

Table 2. % oversize of 100 mesh sieve, density and dry matter content of each grinding process which is applied to raw materials of art tile slip prepared by the representative recipe (Recipe No.1).

Mill Code	% oversize of 100 mesh sieve*	Density (gr/l)	Dry Matter Content (%)
M1-A	2.11	1558	57.70
M2-A	2.44	1566	57.40
M3-A	1.98	1560	57.40
M4-A	1.70	1557	58.80
M5-A	2.19	1526	55.60
M6-A	2.30	1529	56.10
M7-A	2.16	1515	56.50
M8-A	2.10	1547	57.60
M9-A	2.06	1544	57.60
M10-A	2.28	1552	57.60

* Residual % weight of sludge which remained on 100 mesh sized sieve by using 1 liter of aqueous sample of ground raw materials.

Table 3. % oversize of 100 mesh sieve, density and dry matter content of each grinding process which is applied to raw materials of art tile slip prepared by new recipe (Recipe No.2).

Mill Code	% oversize of 100 mesh sieve*	Density (gr/l)	Dry Matter Content (%)
M1-B	1.96	1549	57.20
M2-B	2.05	1544	57.60
M3-B	2.15	1520	56.65
M4-B	2.23	1554	57.65
M5-B	2.32	1529	56.10
M6-B	2.21	1524	55.80
M7-B	2.31	1509	54.90
M8-B	1.98	1540	57.00
M9-B	1.80	1535	53.20
M10-B	2.00	1540	54.95

* Residual % weight of sludge which remained on 100 mesh sized sieve by using 1 liter of aqueous sample of ground raw materials.

One of the most encountered problems in the production field is to remove the filter press cake from the steel plates. In case of high moisture the slip cakes may become stickier and resist being collected in one piece. Even though they are taken in some way, the higher moisture value would affect the vacuum press by sticking on the spiral stirrer resulting in an extremely soft mud which would not be appropriate for the latter processes. Consequently, efficiency of the filter press can be accepted as the key point of the production.

The results obtained in this study exhibited that the moisture contents of the filter press slip cakes varied from 18.92 to 21.14 (%) for the recipe no.1 (Table 4) and from 18.75 to 20.45 for the recipe no.2 (Table 5). It was seen that the moisture contents were decreased during the use of the new recipe. Furthermore it was also noticed that the decline in moisture content has positively affected the efficiency of the filter press (up to % 97.95).

Table 4. The moisture content values of slip cakes produced by filter press with 15 bar pressure using the representative recipe (Recipe No.1). Also efficiency of press and number of flawless and defective slip cakes are given.

Filter Press Code	Moisture Content (%)	Number of Flawless Slip Cakes	Number of Defective Slip Cakes	Efficiency of Press (%)
P1-A	20.80	84	14	85.71
P2-A	20.50	80	18	81.63
P3-A	20.30	80	18	81.63
P4-A	18.92	87	11	88.77
P5-A	19.80	70	28	71.42
P6-A	20.01	86	12	87.75
P7-A	19.90	74	24	75.51
P8-A	21.08	90	8	91.83
P9-A	21.14	90	8	91.83
P10-A	20.15	90	8	91.83

Table 5. The moisture content values of slip cakes produced by filter press with 15 bar pressure using new recipe (Recipe No.2). Also efficiency of press and number of flawless and defective slip cakes are given.

Filter Press Code	Moisture Content (%)	Number of Flawless Slip Cakes	Number of Defective Slip Cakes	Efficiency of Press (%)
P1-B	19.08	91	7	92.85
P2-B	19.36	89	9	90.81
P3-B	20.05	88	10	89.79
P4-B	19.80	88	10	89.79
P5-B	18.76	95	3	96.93
P6-B	20.45	87	11	88.77
P7-B	19.90	90	8	91.83
P8-B	20.00	87	11	88.77
P9-B	19.45	90	8	91.83
P10-B	18.75	96	2	97.95

Comparison of physical properties of cylindrical vacuum-packed plastic slips formulated with the representative and new recipes are given in Table 6. The "air control" results showed that the vacuum press worked properly so as to avoid the occurrence of air or bubbles thanks to the lower moisture content achieved by reducing clay content, particularly the bentonite which has high water absorption (up to 2-10 times of its own volume) resulting in swelling [15,16]. Bentonite was not totally removed from the recipe due to its rheological features and plasticity [17-19]. The results also showed that the processability, glaze conformity and the firing color of the vacuum-packed plastic slips were convenient for both recipes. Finally it was observed that while dry shrinkage value decreased, firing shrinkage value increased on average after the recipe has been changed. It is thought that the reduction of the clay amount was the main reason for such shrinkage values due to its high water absorbance character [20].

Table 6. Air control and forming performance of cylindrical vacuum-packed plastic art tile slips. Also the firing color, glaze conformity (910-920^{0}C) and average percentage of dry (150^{o}C) and firing shrinkage (1050-1080^{0}C) of the slips produced with the representative and new recipes.

Recipe	Air Control	Taking Shape	ADS (%)	AFS (%)	Firing Color	Glaze Conformity
No.1	Not Observed	Appropriate	4.07	4.45	Light Cream	Suitable
No.2	Not Observed	Appropriate	3.27	5.79	Light Cream	Suitable

ADS: Average Dry Shrinkage; AFS: Average Firing Shrinkage

4. Conclusions

In Kutahya, art tile masters have only a few alternatives to buy vacuum-packed art tile slip because there are a limited number of manufacturers who have almost the same problems in their plants since they almost use the same or familiar raw materials and technologies. The most common problem is to remove the excess humidity of the slip cakes achieved from the filter press. So all these are the main reasons why a representative recipe has been created instead of the current ones used by the masters and enterprises.

Although the filter press process seems as a problem by itself, some other important parameters such as time, work and energy losses occurring due to the excess moisture content of plastic slip cakes produced by the filter press make this process more important. Excessive use of energy and long working time (about 8-10 hours) are the other issues in this process, and these parameters bring continuous problems in further processes (vacuum press and forming).

As a result of this study, filter press cakes with less moisture content have been produced under constant filter press pressure and operating time by using a new recipe including less clay content and higher amounts of dolomite and quartz. Ease of operation and productivity of vacuum press have also been improved in this way. Conformity of glaze (lead-containing glaze used by most of the art tile masters in Kutahya) has been provided and negligible changes were observed in colors of the ultimate ware. In order to ensure the continuity of production in the factory, in which the study was made, this preliminary study has been carried out on an industrial scale and 20 tones of dry raw material were used for each recipe. And that was the main reason why the raw material ratios have not been drastically changed. After this preliminary work further studies would be carried out on a laboratory scale and should be very sensitive while practicing the results on an industrial scale. It is believed that the results obtained in the present study would be directive and useful for both the researchers and producers.

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