Oct. 3, 1972 F. E. RICHTER 3,695,960

FABRICATING RELATIVELY THICK CERAMIC ARTICLES

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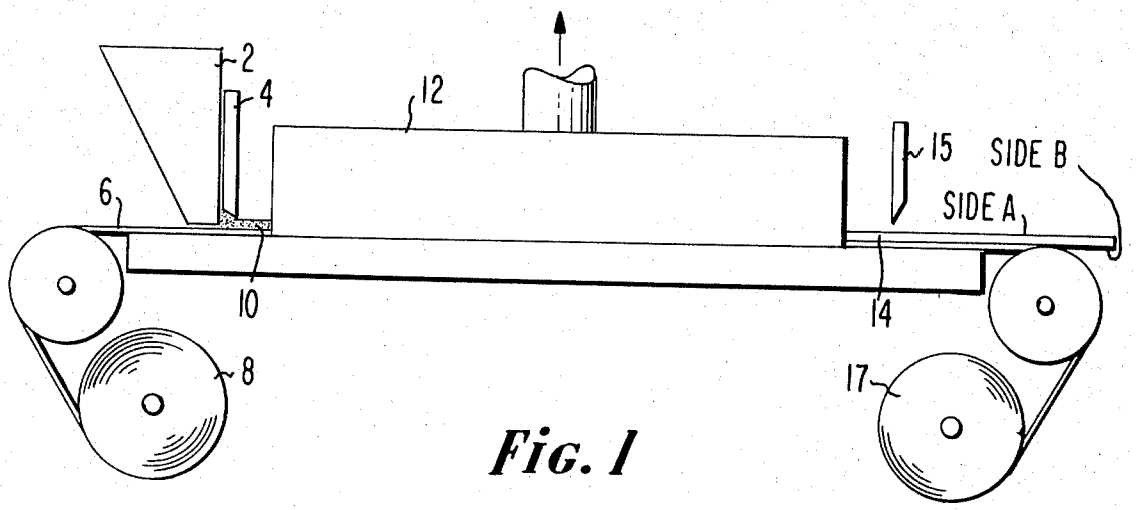

Fig. 1

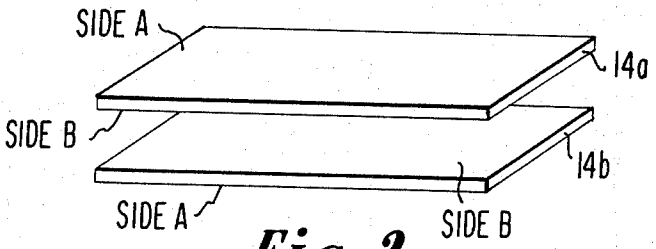

Fig. 2

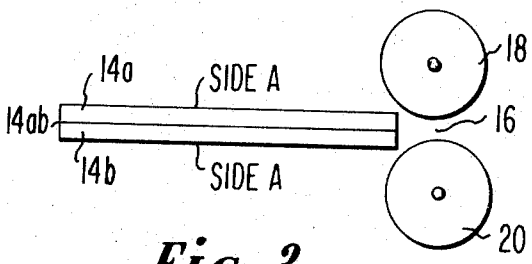

Fig. 3

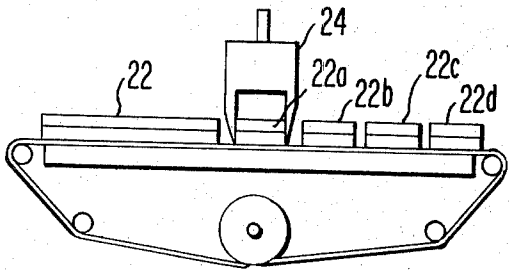

Fig. 4

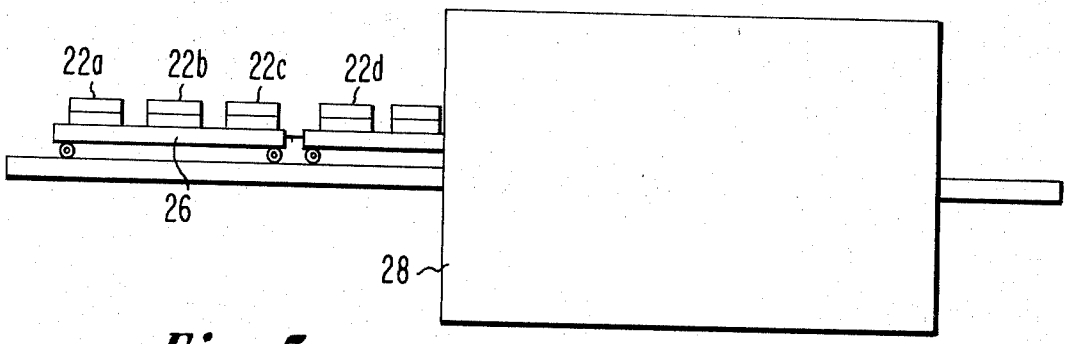

Fig. 5

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FABRICATING RELATIVELY THICK CERAMIC ARTICLES

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U.S. Cl. 156—89 8 Claims

ABSTRACT OF THE DISCLOSURE

A relatively thick ceramic article is fabricated by casting a ribbon of slip upon a smooth surface; drying the slip to form a sheet of green ceramic; cutting the green ceramic sheet into pieces; positioning two of the pieces together so that those surfaces contact each other that formerly faced the smooth surface; passing the pair of pieces through the rolls of a calender to form a laminate; and firing the laminate to mature the ceramic.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to improved methods of fabricating relatively thick ceramic articles.

Description of the prior art

Ceramic articles have been made by mixing a plasticizer, a solvent for the plasticizer, a binder, and the powdered mineral constituents of the ceramic to form a thick-flowing mixture which has a syrup-like consistency and is known as a slip. The slip is deposited as a layer of uniform thickness on a surface. The layer of slip is dried by heating it to drive off the solvent. The dried layer is the green ceramic, and is readily cut into parts of the desired shape and size. These parts are then fired at a high temperature to produce the finished or matured ceramic.

Although matured ceramic parts having a thickness of up to about 0.635 mm. are conveniently made in this manner, when relatively thick ceramic articles are required, for example matured ceramic plates having a thickness of about 1.27 mm., the time required to dry the slip increases so markedly that the cost of the product is increased. In fact, the drying time of the slip appears to increase exponentially with the thickness of the slip. In order to avoid the increased drying time required to drive off the solvent from a thick layer of slip, a relatively thin layer of slip is dried to form the green ceramic as a sheet having a thickness of about ½ of the desired thickness. This sheet is cut into pieces of suitable size, and one piece is bonded to another piece to form a laminate having a thickness which is twice that of the original sheet. When this laminate is fired at a temperature high enough to mature the ceramic, the two green ceramic pieces fuse together, and form a single monolithic body of the matured ceramic having a thickness which is twice the thickness obtained when a single sheet of the green ceramic is matured.

Various methods have been employed to bond two sheets of green ceramic together. One method is to wet the surfaces of the two green ceramic sheets with a solvent such as isopropyl alcohol, place one sheet on another, and employ a light pressure of about 70 grams per square centimeter to laminate the two sheets. However, the two sheets have a tendency to delaminate during handling, and laminates thus made produce poor results in production. Furthermore, the alcohol utilized is toxic and flammable, and therefore not desirable for mass production. Moreover, the process is too slow, since it was found necessary to dry out the alcohol overnight before firing the green ceramic.

Another method of forming the laminate is to position the two green ceramic sheets in a press with heated platens. A temperature of about 115° C. and a pressure of about 29 to 71 kilograms per square cm. is sufficient to laminate the two green ceramic sheets together. However, the process is rather slow for mass production purposes. Furthermore, it was found that various important parameters of the finished product, such as the percent shrinkage in the length and width and thickness directions, could not be controlled sufficiently closely by this method.

Another method of laminating two green ceramic pieces is to position one piece on top of another, and pass the pair of pieces through a calender, that is, between two pressure elements such as rolls, which can be heated. The distance between the two rolls, known as the nip, can also be adjusted to apply the desired pressure between the two green pieces. Although green ceramic pieces can be laminated in this manner, problems arise because when the green ceramic laminate is fired to form a monolithic matured ceramic article, the percent shrinkage is different in the length and height and width directions than the percent shrinkage in those directions for a single sheet of green ceramic. From a production standpoint, it is desirable to have the shrinkage factors be the same for the single ceramic sheet and the laminated ceramic article, so that the same tooling can be used for both.

SUMMARY OF THE INVENTION

Two pieces of green ceramic are positioned next to each other with their casting surfaces contacting each other. The pair of pieces is laminated by running the pair through the pressure elements of a calender. The pressure elements are preferably rolls which are heated to a temperature of about 90° C. to 100° C., and are spaced apart a distance of about 3% to 15% less than the combined thickness of the pair of green ceramic pieces. The laminate thus formed is then fired at the maturing temperature of the ceramic to form a relatively thick monolithic ceramic article.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an elevation view of slip casting and drying apparatus which may be used in carrying out the method of the present invention;

FIG. 2 is a perspective view of 2 green ceramic sheets in position to be laminated according to the present method,

FIG. 3 is an elevation view of the ceramic sheets of FIG. 2 about to be passed between calender rolls,

FIG. 4 is an elevation view of the calendered sheets of FIG. 3 being subdivided into smaller units, and

FIG. 5 is an elevation view showing the small units of FIG. 4 being fired.

THE PREFERRED EMBODIMENTS

EXAMPLE I

A ceramic slip is prepared by mixing the dry ingredients, and then adding the liquid ingredients. In this example the dry ingredients consist of powdered alumina, powdered silica, powdered magnesium carbonate, and powdered calcium carbonate. As a specific example, the powdered alumina or Al_2O_3 is 77.1% by weight of the dry mix; the powdered silica or SiO_2 is 7.7% by weight of the dry mix; the powdered magnesium carbonate or $MgCO_3$ is 8.2% by weight of the dry mix; and the powdered calcium carbonate or $CaCO_3$ is 3.7% by weight of the dry mix. A dry binder such as polyvinyl butyral is added in the amount of 3.3% by weight of the dry mix. After the dry ingredients have been ball milled, a wet plasticizer is added to the mixture. In this example, the plasticizer is dibutyl phthalate, and is added in the amount

of 7 ml. per kilogram of the dry powder. Last, a solvent for the plasticizer and binder is added. In this example, the solvent consists of trichlorethylene, and is added in the amount of 0.29 liter per kilogram of powder.

The above ingredients are thoroughly mixed to form the thick flowing slip. The slip is now cast as a continuous ribbon on a smooth surface. In this embodiment, a quantity of the slip is placed in a storage hopper **2** (FIG. 1) and is dispensed by doctor blading with a doctor blade **4** on a moving continuous belt **6** of a smooth plastic unwound from a roll **8**, which plastic may for example be a thermosetting highly cross-linked polyester such as Mylar. A ribbon of slip **10** of uniform height and width is thereby obtained. In this example, the thickness of the wet slip is about 1 mm.

The continuous ribbon of slip **10** is now transported by the plastic belt **6** through a drying tunnel **12**. Here the wet slip is heated at a temperature just sufficient to drive off the volatiles, such as the solvent. In this example, the wet slip is heated at a temperature of about 24° C. at the tunnel entrance to 54° C. at the tunnel exit, and remains in the drying tunnel for a period of about 20 minutes.

When the material emerges from the drying tunnel **12**, it has become a continuous sheet **14** of the green ceramic. In this example, the thickness of the green ceramic sheet is 0.825 to 0.876 mm.

When the green ceramic sheet **14** emerges from the drying tunnel **12**, advantageously the exposed upper surface, side A, of the green ceramic sheet is printed with a series of lines or other indicia (not shown) for identification purposes.

The contniuous sheet **14** of green ceramic is now cut into a plurality of pieces **14***a*, **14***b*, etc. (FIG. 2) of the desired size and shape with a blade, and the Mylar belt **6** is rolled up into a roll **17**. Next, one piece **14***a* of the green ceramic is positioned on another piece **14***b* of the green ceramic to form a pair of pieces **14***ab* (FIG. 3). The pieces **14***a* and **14***b* are positioned so that those surfaces, sides B (hereinafter called casting surfaces), of the pieces that formerly faced the smooth surface on which the slip was cast, in this example the surface of the plastic belt **6**, are contacting each other. Since the upper surfaces of each sheet have been marked with ink lines, it is merely necessary to position the pieces with their unmarked sides facing each other.

Each pair of green ceramic pieces is now passed through the rolls of a calender (FIG. 3) to form a laminate. The nip or distance, **16** between the rolls **18** and **20** of the calender is set at a distance about 3% to 15% less than the combined thickness of the two green pieces **14***ab*. In this example, the combined thickness of the two green pieces **14***ab* is 1.67 mm. and the rolls **18** and **20** of the calender are spaced apart 1.5 mm. The laminate **22** (FIG. 4) which emerges from the calender is about 1.6 mm. thick.

It has been found that, for best results, the temperature of the rolls should be maintained at 90° C. to 100° C. during the lamination, and the speed at which the pair of green ceramic pieces is passed through the calender should be about 75 to 110 cm. per minute. At higher speeds, lamination becomes poor, while at lower speeds the shrinkage percentages are affected.

When two green ceramic pieces are laminated in this manner, they cohere well. In contrast, if the casting surfaces of the two pieces do not contact each other during the lamination step, they do not cohere well, and have a tendency to delaminate. The poor results obtained when the surfaces laminated are the surfaces opposite the casting surfaces are believed due to the circumstance that during the drying step the solvent escapes from the slip through the surface opposite the casting surface. The solvent probably carries some binder with it, but since the binder is not volatile, it is left at the slip surface opposite the casting surface. The concentration of binder at this surface is the probable cause of poor lamination for this surface.

Moreover, it has been found that the present shrinkage in three directions for the fired laminate formed as described above becomes very close to the percent shrinkage of a single sheet. A more uniform and reproducible product is thereby obtained.

Predetermined portions of each laminate are removed by cutting each laminated sheet **22** into a plurality of smaller pieces **22***a*, **22***b*, **22***c*, **22***d*, etc. by a die **24**. The last step is to fire each laminate at a temperature sufficient to cure the ceramic and form a relatively thick monolithic mature ceramic article. This may be done by stacking the laminated pieces on saggers carried by carts **26** (FIG. 5) and run through a firing oven **28**. In this example, each laminate is fired at a temperature of about 1475° C. to 1500° C. for about 2 hours. The laminate shrinks during this step, so that the thickness of the mature ceramic article in this example is about 1.27 mm.

EXAMPLE II

In the previous embodiment, the dry green ceramic sheet was cut into pieces of predetermined size and shape; pairs of these pieces were laminated; and the resulting laminates were fired at the maturing temperature of the ceramic to form a relatively thick monolithic ceramic article.

In the present example, two sheets of green ceramic are formed by dispensing quantities of a ceramic slip onto a smooth surface, which may for example be the surface of a continuous plastic belt as in Example I. The slip thus cast is dried to remove volatiles therefrom. The two green ceramic sheets are positioned together so that their mutually contacting surfaces are the casting surface, that is, the surfaces which formerly faced the smooth surface on which the slip was cast.

The two green sheets are then pressed by a calender. Suitably, the two green sheets are passed through calender rolls which are maintained at a temperature of 90° C. to 100° C., and have a nip or spacing distance between the rolls which is 3% to 15% less than the combined thickness of the two green sheets.

The laminate thus formed is fired to the maturing temperature of the ceramic to form a relatively large and thick monolithic ceramic plate, which may be subsequently coated or metallized or subdivided as desired.

I claim:

1. A method of fabricating a relatively thick ceramic article comprising:

(a) preparing a slip by mixing together a plasticizer, a binder, a solvent for said plasticizer and binder, and the powdered mineral constituents needed to make said ceramic;

(b) casting a continuous ribbon of said slip on a smooth surface;

(c) drying said ribbon of slip by heating it at a temperature sufficient to drive off said solvent, thereby forming a continuous sheet of green ceramic;

(d) cutting said green ceramic sheet into pieces and taking one-half of said pieces and uniting them with the other half of said pieces;

(e) by positioning each green ceramic piece on another green ceramic piece to form a plurality of pairs of pieces, the surfaces of said pieces that formerly faced said smooth surface contacting each other;

(f) laminating said pairs of pieces by passing each of said pairs through calender rolls, said rolls being heated to a temperature of about 90° C. to 100° C.; and,

(g) firing the laminated pairs to the maturing temperature of the ceramic to form a relatively thick monolithic ceramic article.

2. The method of claim **1**, wherein said smooth surface is the surface of a continuous plastic belt.

3. The method of claim 1, wherein said calender rolls are spaced apart a distance which is 3% to 15% less than the combined thickness of each of said pairs of pieces.

4. The method of claim 1, wherein said pairs of pieces are passed through said calender rolls at the rate of about 75 to 110 centimeters per minute.

5. A method of fabricating a relatively thick ceramic plate comprising:

(a) forming two cast sheets of green ceramic each of which is large enough to be divided into many smaller units, by dispensing quantities of a ceramic slip onto a smooth surface, and drying the dispensed slip to remove volatiles therefrom;

(b) positioning the two green ceramic sheets together, so that their mutually contacting surfaces are the casting surfaces;

(c) pressing said two sheets with a calender having pressing elements which are maintained at a temperature of 90° C. to 100° C.; and

(d) firing the resulting laminate to the maturing temperature of the ceramic to form a relatively thick monolithic ceramic plate.

6. The method of claim 5, wherein said smooth surface is the surface of a continuous plastic belt.

7. The method of claim 5, wherein said calender pressure elements are rolls, and said rolls are spaced apart a distance which is 3% to 15% less than the combined thickness of said two sheets.

8. The method of claim 5, wherein said two sheets are passed through said calender rolls at the rate of about 75 to 110 centimeters per minute.

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