PROCESS FOR CONTINUOUSLY ANNEALING A FUSED CAST REFRACTORY BODY

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Int. Cl. C04b 35/60
Field of Search 264/66, 332, 346, 348

References Cited
UNITED STATES PATENTS
1,878,870 9/1932 Linder 264/128 X
2,154,153 4/1939 Easter et al. 264/332 UX

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ABSTRACT
A process for continuously annealing a fused cast refractory body, in order to obtain a crack-free product, in which the fused cast refractory body is placed on a suitable preheated carrier which has been previously heated to a temperature of greater than 500°C in a preheat chamber, and is charged into an annealing tunnel which is divided into a hot zone and a cooling zone having at least one cooling section.

9 Claims, 3 Drawing Figures
PROCESS FOR CONTINUOUSLY ANNEALING A FUSED CAST REFRACTORY BODY

This is a continuation, of application Ser. No. 67,939, filed Aug. 28, 1970 now abandoned.

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to a process for annealing a fused cast refractory body and more particularly to a process for continuously annealing a fused cast refractory body so as to produce a product which is free of cracks.

2. Description of Prior Art

According to most conventional processes, fused cast refractory products are prepared by admixing refractory materials and additives in a suitable proportion and fusing the composite in an electric furnace to prepare a melt. The melt is then cast into a suitable mold. Fusion of the refractory product usually occurs at temperatures of higher than 2000°C, and accordingly, it is necessary to slowly and uniformly cool the fused case refractory body so as to avoid localized stress concentrations due to formation of temperature gradients during the cooling steps which can tend to crack the cast melt. The necessary cooling procedure has conventionally been accomplished by a number of different techniques, including covering the cast fused melt with an "annealing powder," i.e., a particulate heat insulator such as diatomaceous earth or the like, thereafter slowing cooling the covered melt in natural air currents. These prior techniques, however, have a number of distinct disadvantages and do not entirely eliminate the occurrence of stress cracking in the melt body. For instance, although theoretically the use of an annealing powder should be effective in controlling the cooling rate, as yet, no entirely suitable annealing powder has been reported. A suitable annealing powder should have a low coefficient of contraction and should have a high softening point. It should not melt into or react with the cast body. It should have a low thermal conductivity and should be inexpensive and/or readily recoverable. The use of an annealing powder has certain other distinct disadvantages when operating within certain temperature ranges. For instance, the speed of cooling when using an annealing powder is so low that complete cooling frequently requires up to several days.

Moreover, the use of an annealing powder causes powder dust and deleteriously affects the working environment.

SUMMARY OF THE INVENTION

Accordingly, it is one object of the present invention to provide an improved process for annealing a fused cast refractory body, whereby a fused cast refractory product can be quickly and economically cooled without significant cracking or strain development.

It is another object of this invention to provide a process for continuously producing a fused cast refractory product without significant crack or strain development.

A further object of this invention is to provide a process for continuously annealing a fused cast refractory body without the use of an annealing powder.

A still further object of this invention is to economically provide a process for producing a fused case refractory product by a rapid, but controlled, cooling procedure.

Another object of this invention is to provide a process for producing a fused cast refractory product by cooling the product under improved environmental conditions.

These and other objects have now herein been attained by the process of continuously passing the fused cast product through a annealing tunnel which contains zones of controlled heating and controlled cooling.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic cross-sectional view of one embodiment of an apparatus formed according to the teachings of this invention:

FIG. 2 is a schematic longitudinal sectional view of the apparatus taken along line A—A' in FIG. 1:

FIG. 3 is a schematic longitudinal sectional view of the apparatus taken along line B—B' of FIG. 1.

DESCRIPTION OF PREFERRED EMBODIMENTS

Solidification of a refractory melt in a mold usually occurs initially at the surface of the melt and, as cooling continues, proceeds inwardly toward the center of the melt. During solidification, the refractory materials will form multiple phases of a crystalline material, in which glassy matrix are interspersed. In order to prevent cracking of the body as solidification proceeds, it is necessary to insulate the outer surface of the cast refractory body so as to avoid the creation of undesirable internal stresses which can weaken the cast product. This is accomplished by cooling the melt in an environment in which a predetermined temperature range is maintained during the solidification procedure. The precise temperature necessary during the cooling procedure will vary depending upon the particular materials used in forming the melt. Good results are obtained when the fused cast refractory body is solidified at a temperature between the temperature of the lowest melting point of crystalline component of the body and the temperature of about 300°C below the lowest melting point of crystalline component of the body, or, where a glassy matrix is present, at a temperature of about 300°C less than the solidifying point of such glassy matrix, so that any internal stresses developing within the body during the solidification will be minimized. Preferably, the solidification or crystallization temperature is maintained at between 50°C to 300°C less than the temperature of the melting point of the lowest melting crystalline component or the solidifying point of the glassy matrix.

Table 1 shows the heating temperatures and periods which will permit satisfactory solidification of a cast refractory body in the solidification chamber (bot zone) according to this invention.

<table>
<thead>
<tr>
<th>Components of Cast Refractory Product</th>
<th>Required Temperature</th>
<th>Time for Holding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃-SiO₂ type fused cast refractory product</td>
<td>More than 1200°C</td>
<td>More than 1 hour</td>
</tr>
<tr>
<td>ZrO₂-Al₂O₃-SiO₂ type fused cast refractory product</td>
<td>More than 1100°C</td>
<td>More than 1 hour</td>
</tr>
</tbody>
</table>
3,723,593

According to the present process, the cast refractory body is held at the temperature and time period specified in Table 1 until solidification is complete, and is then cooled to room temperature. If the cooling speed exceeds the designated cooling speed, cracks can develop in the cast product. If cooling occurs too slowly, the efficiency of the annealing operation will be undesirably reduced. The precise time and temperature to be used in each instance, will depend upon the particular refractory materials used in the melt. By using these techniques, however, the annealing time can be reduced between one-third and one-fifth of the time required for conventional annealing processes. Therefore, instead of the 5 to 10 days presently required for annealing a fused cast refractory body, it is now possible to reduce the annealing time to 1 to 2 days.

In the method of this invention, the refractory materials are fused in an electric furnace or the like, and the melt is cast into a mold and the mold is placed on a suitable preheated carrier. The carrier with the mold is then passed into a solidification chamber (hot zone) of annealing tunnel wherein heat is slowly radiated from the fused cast refractory body, causing solidification. The body is then brought into a cooling zone (cooling chamber) of annealing tunnel wherein annealing of the refractory body is completed. When practiced on an industrial level, the carrier may be a truck or a railroad car which can be carried through a tunnel which is divided into a solidification chamber (hot zone) and a cooling chamber (zone) having at least one cooling section.

If the temperature of the carrier is too low, the outer portion of the melt will be prematurely solidified which can cause a build-up of stress as the center portion of the melt begins to solidify and contract. Accordingly, the carrier should be preheated, preferably at a temperature of greater than 500°C and, more preferably, to a temperature of greater than 700°C, so that as the mold enters the hot zone of the annealing tunnel, most portion of the melt will still be in an unsolidified or molten state. Moreover, carrier is suddenly heated, if carrier is not preheated and cracks occur in the refractory mass constructing carrier. One suitable method for preheating the carrier is to pass a hot combustion gas over the carrier in a suitable preheating chamber.

After entering the hot zone of the annealing tunnel, the refractory melt will tend to lose heat by radiation and convection to the heated but relatively cooler walls of the chamber.

Where the environment in the annealing tunnel is isolated, such as by means of a damper device which is designed to prevent the entrance of air currents into the tunnel, the cooling speed of the refractory body will be proportional to the difference between the temperature of the body surface and the ambient temperature within the chamber. Accordingly, the rate of cooling of the refractory body can be controlled by adjusting the ambient temperature within the cooling zone (chamber) and by controlling the speed of the carrier moving through the cooling zone.

It has been found that when the ambient temperature is lower than the temperature of 200°C below surface temperature of the refractory body, the fused cast refractory body will be cooled too quickly and some degree of cracking will occur. Accordingly, it is preferable to control the ambient temperature within the cooling zone to less than 200°C below the surface temperature of the body. Preferably, the ambient temperature of the cooling zone should be as close to a 200°C differential as practicable, for best results. Most preferably, the temperature differential between the cast refractory body surface and the ambient temperature of cooling zone should be between 50°C and 200°C.

In order to provide a suitable environment within the cooling zone, the temperature in the first cooling section of cooling zone should be greater than 600°C. The first cooling section is preferably constructed with double walls and/or double ceilings of different thicknesses and different heat transfer rates. Cooling air should be passed between the double walls and double ceilings to regulate the temperature within the chamber.

The second cooling section of cooling zone is preferably divided into at least two sub-sections having different environmental temperatures. The first sub-section of second cooling section of cooling zone should have an environmental temperature of more than 150°C, and preferably higher than 200°C. The environmental temperature, however, should be lower than 600°C. This sub-section may be constructed with walls and ceilings having water cooling tubes which are placed within the walls or on the outer surface of the wall and/or the ceiling.

The second subsection of second cooling section of cooling zone should have a temperature of lower than 250°C and preferably lower than 200°C. This sub-section may be cooled by blowing cooling air or a forced convection of air through the chamber.

If desired, the second sub-section of second cooling section can be situated outside the chamber. Temperature control in each zone can be achieved by the use of movable dampers. If the difference in temperature between the environmental temperature and the temperature of the body surface is too small, an unduly extended period of time is required for the annealing process. Accordingly, temperature differentials of greater than 50°C but less than 200°C is preferred.

Referring now to the drawings wherein like numerals are used to designate corresponding parts throughout the several figures, there is shown one embodiment of an annealing apparatus constructed according to the teachings of the present invention.

The annealing tunnel is provided having a hot zone 1 of solidification chamber a cooling zone 2, and a preheat zone 3. The three zones are connected by means of a railway system 5 and traversers 6 and 7. A flue 4 is provided adjacent to the hot zone 1 and the preheating
The hot zone in the tunnel is heated by means of a plurality of combustion burners, situated on opposite sides of the chamber. Good results are obtainable when three burners are separated by a space of 2000 mm. at both sides, respectively. An electric element can be used instead of the combustion burners if desired. A high temperature combustion exhaust gas can be introduced into the preheat zone through outlet 9 provided on the sidewall of the hot zone. The high temperature gas provides the heat for said preheating zone 3, in order to preheat the truck type carrier 10. The combustion gas is then exhausted through chimney 11 by a suitable vent. The preheating zone can be positioned in alignment with the hot zone, if desired, so that the hot zone, the cooling zone and preheating zone can be provided on the same straight rail. The fused cast refractory body can then be placed in the carrier in the heating zone through a gate provided through the ceiling or sidewall of the hot zone or suitable heating zone for this purpose. The cooling zone 2 is usually separated into two or more sections. As shown in the drawings, the cooling zone is separated into four sections, i.e. a first section 12, a second section 13, a third section 14 and a fourth section 15, so that the fused cast refractory body can be rapidly cooled in a controlled manner without the development of cracks or undesirable regions of high strain. The first section 12 is constructed with a double ceiling 19, a double sidewall 20. The ambient, or environmental temperature of section 12 is regulated by passing a cooling gas, such as air, between the double walls. The second section 13 is constructed with a ceiling 18 and sidewalls 20 in which cooling tubes 22 are provided. The ambient or environmental temperature of this section is regulated by passing a cooling fluid, such as water, through the tubes 22. The third section 14 is provided with cooling tubes 23 embedded within the surface of ceiling 19. The ambient or environmental temperature of this section is regulated by passing cooling water through the tubes 23. The fourth section 15 is provided with an air outlet 24 and with an air inlet 25. The ambient or environmental temperature of this section is regulated by recycling air using fan 16. If necessary, atmospheric air can be ejected into section 15, in order to cool the truck and the product.

In the annealing tunnel shown in the drawings, it is preferable to provide a flexible damper (17 and 17') at the entrance to each zone or each section in order to prevent cooling too quickly by air transfer between the zones or sections. Good results are obtained when the cooling speed is about 30°C to 90°C per hour when the temperature is greater than 1,000°C, about 50°C to 120°C per hour, when the temperature is between 600°C and 1,000°C, and about 20°C to 80°C per hour, when the temperature is between 200°C and 600°C.

In the operation of this invention, the fused refractory body is cast into the mold and is placed on a truck type carrier which has bee preheated to a temperature greater than 500°C, and preferably greater than 700°C. The truck is passed on a traverser 7 along track 5 and through gate 18 into hot zone 1, which is heated at the predetermined temperature, whereby annealing occurs. A series of trucklike carriers and molds can be continuously fed into the hot zone at predetermined intervals. Each truck entering the hot zone is gradually cooled to room temperature during the course of being transferred from the hot zone to the final section of the cooling zone 2. The truck is then transferred to rail 5, where the cast refractory product is removed from the truck and the truck is recycled back to the preheating zone 3.

**EXAMPLE**

A mixture of refractory materials comprising 72 to 80 percent by weight of Al₂O₃, 15 to 25 percent by weight of SiO₂, 0.5 percent to 3 percent by weight of TiO₂, 0.5 to 2 percent by weight of Fe₂O₃ and minor amounts of CaO, MgO, is melted at a temperature of above 1,500°C and is cast into a sand mold having an internal volume of 200 × 200 × 300 mm. Ten molds are placed onto a truck having a table area of 1,000 × 2,000 mm., which has been preheated to a temperature of greater than 700°C in a preheating chamber. Every 30 minutes, the truck is successively introduced in the hot zone having a temperature of about 1,400°C.

The conditions of the heat treatment of the fused cast refractory bodies are as follows.

**Times in the solidification chamber (hot zone)**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Time (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 600°C</td>
<td>60 min.</td>
</tr>
<tr>
<td>200°C to 600°C</td>
<td>480 min.</td>
</tr>
</tbody>
</table>

**Cooling Time**

- Indirect cooling 70°C to 100°C/hr. by cooling air in space of double wall
- Cooling by water in tube 50°C to 80°C/hr. 90°C to 180°C
- Direct air blowing 10°C to 40°C/hr. 120°C to 200°C

Total cooling time as measured from the time the truck enters the hot zone to the time it leaves the cooling zone, is 32 hours. No undesirable cracking was found on any of the cast refractory products produced according to the fusing and annealing process.

Having now fully described the invention, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made without departing from the spirit or scope of the invention.

What is claimed as new and intended to be covered by letters patent is:

1. A process for continuously annealing a fused cast refractory body consisting of; casting a melt of refractory materials selected from the group consisting of Al₂O₃, SiO₂, TiO₂, Fe₂O₃, ZrO₂, Na₂O, MgO and Cr₂O₃, without an annealing powder into a mold; holding said melt at a solidifying temperature of between 1,200°C and the melting point of the lowest melting point crystalline component or the melting point of the glassy matrix material, if the melt contains 1 glassy matrix material, for between 30 minutes to 2 days, until crystallization occurs; and,

gradually cooling said crystallized product so that cracking of the product is substantially minimized.

2. The process of claim 1 wherein said mold is placed on a carrier which has been preheated at a temperature of greater than 500°C prior to receiving said mold.

3. The process of claim 2 wherein said cooling is conducted in a zone having an ambient temperature of from 90°C to 200°C less than the surface temperature of the crystallized product.
4. The process of claim 1 wherein said cast refractory material is an Al₂O₃—SiO₂ type fused cast refractory product which is solidified under an initial temperature of greater than 1,200°C for more than 1 hour.

5. The process of claim 1 wherein said cast refractory material is a ZrO₂—Al₂O₃—SiO₂ type fused cast refractory product which is solidified under an initial temperature of greater than 1,100°C for more than 1 hour.

6. The process of claim 1 wherein said cast refractory material is an Al₂O₃ type fused cast refractory material which is solidified under an initial temperature of greater than 1,400°C for more than 30 minutes.

7. The process of claim 1 wherein said cast refractory material is a MgO—Cr₂O₃—Al₂O₃—Fe₂O₃(FeO) type fused cast refractory product which is solidified under an initial temperature of greater than 1,300°C for more than 30 minutes.

8. The process of claim 3 wherein said gradual cooling procedure occurs in at least two sections wherein the temperature in said first section is between 150°C and 600°C, and the temperature in a second section is less than 250°C.

9. The process of claim 4 wherein said Al₂O₃—SiO₂ type fused cast refractory product comprises:

<table>
<thead>
<tr>
<th></th>
<th>% by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>72% to 82%</td>
</tr>
<tr>
<td>SiO₂</td>
<td></td>
</tr>
<tr>
<td>TiO₂</td>
<td>15% to 25%</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.5% to 3%</td>
</tr>
<tr>
<td></td>
<td>0.5% to 2.5%</td>
</tr>
</tbody>
</table>

Which is melted and subjected to a hot zone having a temperature of about 1,000°C to 1,400°C and then to a plurality of cooling zones wherein the first section has a temperature of above 600°C, the second section has a temperature of from 200°C to 60°C and the third section has a temperature of less than 200°C.