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(54) CASTING PROCESS USING A CASTING VESSEL HAVING BASIC LINING

(71) We, NIPPON KOKAN KABUSHIKI KAISHA, a company organised and existing under the laws of Japan, of No. 1-2 1-chome, Marunouchi, Chiyoda-ku, Tokyo, Japan and SHINAGAWA SHIRORENGA KABUSHIKI KAISHA, a Company organised and existing under the laws of Japan, of No. 2-1 2-chome, Otemachi, Chiyoda-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:–

This invention relates to a casting process using a casting vessel having a basic lining.

A vessel which receives molten and refined steel, and casts it into the mold, is known as a casting ladle. Such a vessel has a wall which is generally frusto-conical when viewed in vertical cross section and comprises an iron outer shell, a backing layer and a lining.

The lining of known ladles has been composed of chamotte, agalmatolite or other acid or neutral bricks. However, these materials are disadvantageous because their slag resistability is low and erosion by the molten metal is high. In view of such circumstances, there have recently been attempts to compose the so-called basic lining casting vessel by using basic refractories for the lining material which do not readily react with the slag and are excellent in prevention of erosion by the molten metal. But if basic refractories were used for the lining of the side wall of the casting vessel under the same conditions as with acid or neutral refractories, the inherent life of the basic refractories would be greatly reduced because of brittleness and exfoliation of parts thereof fairly deep from the surface of the lining layer owing to thermal or structural spallings, and because adherence of the metal or slag is extreme and its removal is difficult. Thus, the use of basic refractories for the lining of the casting vessel has not been put into general practice. Recently, many studies have been carried out to put into practice the use of such basic linings, and the present inventors have also offered several proposals and have achieved a certain amount of success.

These preceding techniques are roughly divided into an improvement of the structure of the side wall, and a method of controlling the temperatures of the side wall of the vessel. The former technique is known for example, in arrangements having a regenerative layer, namely a refractory brick having a high specific heat, an insulating layer and a backing layer on the basic lining layer (Japanese utility publication No. 51-22111). However, since such structures need a relatively thick regenerative layer, the thickness of the lining layer is in general limited and the life of the lining layer is not increased. Moreover since the extent of expansion of the lining layer is not taken into consideration, thermal stress is generated in the interior of the lining layer which consequently causes exfoliation.

It is also known to heat the side wall to temperatures above 900°C before the vessel holds the molten steel (Japanese patent application No. 51-12329 laid open to public inspection), or to maintain the temperatures within the ladle above 1100°C by means of a cover having a heating means (Japanese patent publication No. 50-5657). For satisfying the above conditions, a burner which has a relatively large heating capacity, or a cover for the ladle are required which lower the operating efficiency inconveniently, and according to studies made thereafter it has been found that there is still room for further improvements.

The present invention has been developed with the background knowledge of these known techniques.

The invention provides a casting process using a casting vessel comprising an iron shell, a backing layer and a basic lining, wherein the backing layer is partially composed of cushion material which has a compressive characteristic of more than 10% up to a pressure 10 kg/cm^2 and the cushion material has a thickness between 7 mm and 50 mm, in which process the surface of the basic lining which contacts molten metal is heated to at least 500°C before the casting vessel receives the molten metal.

An advantage of the invention is that it makes it possible to provide a method of using a basic lining casting vessel which increases the effect of absorbing thermal stress to increase the life of the casting vessel.

Reference is made to our British Patent Specification Serial No. 1601611 (7182/78) which claims a casting vessel comprising an iron shell, a backing layer and a basic lining, wherein the backing layer is partially composed of cushion material having a compressive characteristic of more than 10% up to a pressure of 10 kg/cm^2, and the cushion material has a thickness between 7 mm and 50 mm. This construction enables thermal stresses in the wall of the casting vessel to be absorbed so as to reduce the liklihood of exfoliation of the lining occurring. Such casting vessels can be used in a process according to the present invention.

In a process according to the invention the temperatures of the inner surface of the basic lining is maintained at least 500°C before the vessel receives molten steel. Difference in time between charges creates abrupt change in temperature in the lining, which inevitably occurs in accordance with the locations at a practical working site or with operating conditions in a cycle of receiving-casting metal, whereby stress is concentrated within the side wall so much that even if cushion material is provided it is diffucult to absorb such stress which provides exfoliation. However, according to a process embodying the invention, the inside of the vessel which is to be contacted by molten metal is kept above a predetermined temperature, so that abrupt changes in temperatures may be prevented even if there is a substantial time gap before the next change. Therefore, stress in the lining may be moderated to an extent that cushion material can absorb it. The characteristics of the side wall structure can be utilized thereby, and its durablity further increased.

Embodiments of the invention will now be described by way of example and with reference to the accompanying drawings, in which:

Figure 1 is a vertical cross section showing one example of a known casting vessel;

Figure 2 is a partial cross section showing one example of the casting vessel structure which can be used in a process according to the invention;

Figure 3 is a partial cross section showing another example of the casting vessel structure which can be used in a process according to the invention;

Figure 4 is a graph showing the relationship between the thickness of the cushion material and the life of the basic lining;

Figure 5 is a graph showing compression deformabilities of various cushion materials, and

Figure 6 is a graph showing the relationship between the distance from the inner side of the lining and temperatures in the interior of the lining of the casting vessel.

Figure 1 shows a casting vessel or ladle having a wall which is generally frusto-conical in vertical cross-section and comprises an iron shell 12, a backing layer 11, and a lining 10.

Figures 2 and 3 show casting vessels having basic linings and embodying the invention. In each embodiment a reference numeral 3 is an iron shell, a numeral 2 is a backing placed on the surface of the iron shell 3, and numeral 1 is a basic lining provided on the surface of the backing 2. According to the invention there is provided a cushion material 5 such as a ceramic fiber, an insulating board or other similar materials, which is used partially for the backing layer. So long as a layer of the cushion material 5 is used for the backing layer, its position in the wall of the vessel is not limited. For example, it is used as a part of the backing layer 2 as illustrated in Figure 2, whereby the basic lining 1 is provided on its outer surface with a lining 4 of refractory material, such as the agalmatolite brick or the like, and the cushion material 5 is arranged between the refractory lining 4 and the iron shell 3. In addition, the positions of the cushion material 5 and the refractory backing 4 shown in Figure 2 may be reversed as shown in Figure 3. In summary, the structure is adapted to accommodate thermal stresses set up during casting. However in some case it may be still insufficient in using in the lining of the basic refractories a cushion material for part of the backing layer as mentioned above.

The inventors carried out experiments on a concrete thickness of cushion material 5 to investigate the most effective range thereof. The experiments used three kinds of the ladles of 60t, 180t and 300t. The side wall was of structure shown in Figure 2, and burned magnesite-dolomite brick (Segar Cone No. 7 40, MgO: 85%, CaO: 14%) was used for the basic lining 1, and agalmatolite chamotte brick (Segar Cone No. 32) was used for the backing refractores 4, and ceramic fiber having a thickness of 3 to 60mm was used as the cushion material 5, the thickness being changed to study its relationship with the life of the lining and from which an optimum range for the thickness of 7mm to 50mm was derived. Each of the ladles showed as in Table 1.

TABLE 1

Capacities	60t	180t	300t
mm			
Height	3000	3350	3400
Average diameter	2600	3200	4000
Thickness of lining	70	200	300
Thickness of backing refractories	40	70	95

The test results are shown in the graphs of Figure 4 in which (X) shows changes when the thickness of the lining is 70mm, (Y) shows changes when the thickness is 200mm, and (Z) shows changes when the thickness is 300mm.

As is seen from this table, in each ladle of 60t, 180t and 300t the lives of the linings increase as the thickness increases, and the usefulness of using the cushion material 5 is acknowledged, but if it is too thick, the life of the lining is decreased. Therefore, the problem is determining the useful limit for the thickness of the cushion material 5. The thickness of the cushion material is different in dependence on the thickness of the lining 1, but in general if the cushion material 5 is thin, its stress absorbing effect is weak and so the frequency of exfoliation is too great and the merit of the cushion material is reduced. However if it is too thick, slack occurs in the lining 1 and the backing refractories to shorten considerably the lining life owing to the invasion of the metal into cracks of the lining which can result in difficulties such as dissolving of the vessel. Therefore, the invention specifies that the thickness of the cushion material 5 should preferably not exceed 50% of the basic lining which should have a thickness in the range between 70mm and 300mm. If 50% is exceeded, the thickness of the basic lining 1 becomes relatively thin and the life of the lining could be reduced. The above refers to a cushion material of ceramic fiber, and a further investigation was carried out on various kinds of insulating boards.

Figure 5 shows curves of compression deformability of various kinds of the cushion materials, in which (a) (b) (c) are of insulating boards, and (d) (e) are of the ceramic fibers. As shown in the same, the ceramic fibers (d) (e) show high compression deformabilities in comparision with the insulating boards (a) (b), but such compressive characteristics as of these ceramic fibers are not required for the ordinary stress, and according to the experiments each of the insulating boards (a) (b) (c) had a sufficient cushion effect, especially the insulating boards (b) (c) which showed almost the same results as the ceramic fibers. From such viewpoints it is found that a material which has a compressive characteristic of more than 10% up to a pressure of $10kg/cm^2$, can accomplish the required stress absorbing effect for the cushion material 5, but the material preferably has a compressive characteristic of 40 to 70% up to the pressure of $10kg/cm^2$. Moreover, a material having a compressive characteristic of less than 10% upto the pressure of $10kg/cm^2$, has little capability to absorb the stresses likely to be encountered in use, and is not practical because the lining life is short.

The stress generated in the basic lining 1 is absorbed by using the cushion material 5 for a part of the backing 2 to enable to prolong the life of the lining.

For using in practice a casting vessel having the above mentioned side wall structure, the inventors further make further investigations regarding increasing the stress absorbing effect of the cushion material, and came to the conclusion that the temperatures of the part of the basic lining which in use contacts the molten metal should be at least 500°C before the casting vessel receives the molten metal. This conclussion is based on the following experiments.

When the operation was carried out with the ladle of 180t and a cushion material 5 of ceramic fiber 20mm thick, the lining life was 108 times as shown in Figure 4. This is a considerable improvement in comparison with a conventional structure without cushion material having a life of about 60 times. But when surveying the conditions of use, there were in total 13 times of still air coolings for more than two hours before the next charge after the casting in the receiving-casting cycle, and on several occasions thereafter exfoliation occurred. Next, a thermo-couple (P_t-P_tR_h) was laid in the interior of the basic lining 1 for continuously measuring the temperatures, and at the same time the temperatures within the lining vessel were measured with a radiation pyrometer, when required. The results are shown in graphs of Figure 6, in which a curve (B) is the temperature of a still air cooling for one hour after casting, a curve (E) is the temperature of a still air cooling for two hours after casting, and a curve (A) is a temperature after five minutes after receiving the steel. As seen in Figure 6, the curves (A) and (E) show larger differences in temperature at positions near to the inner side of the vessel. These differences in temperature result from a difference in time between charges which is inevitable in accordance with the locations at a practical work site, the operating conditions and other factors. The above mentioned exfoliation is caused by concentration of stress in the side wall which is so large that the cushion material cannot absorb it, the stress being generated by the abrupt change between the temperatures of the curve (E) or less and that of the curve (A).

For avoiding such abrupt change of the temperature, the inner side of the vessel which contacts the molten steel is heated, before receiving the steel, above the determined temperatures by means of heating means such as a burner, but the problem is to determine an optimum temperature. The inventors kept the lowest temperatures within the vessel at 450°C, 500°C and 600°C for testing the lining lives at the respective temperatures. The curve (D) of Figure 6 is a case where the inside of the vessel is heated to 500°C and the curve (C) is a case where heating was to 600°C. The results thereof are in table 2.

TABLE 2

Lowest temperatures within the vessel	Lives of the linings
450°C	118 times
500°C	160 times
600°C	162 times

It is seen from this table that the lining lives are rapidly improved from a lowest temperature of the vessel of 500°C. In other words, when the inside surface of the vessel which contacts the molten steel, is heated above 500°C, the difference in temperature between the curves (A) and (E) is reduced, and the stress becomes moderate to such an extend that it can be absorbed by the cushion material. In these circumstances, the limit for practical purposes of the desired temperature of the inner surface of the lining is determined to be at least 500°C. Thus, it is important for effectively using the casting vessel to heat the inside of the basic lining of the vessel to at least 500°C. The upper limit of the heating temperature is not specially limited, but when heating with a paraffin oil or heavy oil for about 30 minutes, an upper limit is 1000°C to 1100°C. However, in general, the heating is not carried out for more than 30 minutes, and, practically, to a temperature of 700°C to 900°C for about 10 minutes.

In a vessel according to the present invention, as apparently from each of the above said experiments, part of the backing 2 is substituted with the cushion material 5 of the specified thickness, thereby to absorb stress generated in the basic lining 1 to make use of the inherent longer lives of basic refractories, and when required the inside of the casting vessel is heated above the determined temperature to improve further their durability.

WHAT WE CLAIM IS:–

1. A casting process using a casting vessel comprising an iron shell, a backing layer and a basic lining, wherein the backing layer is partially composed of cushion material which has a compressive characteristic of more than 10% up to a pressure of 10 kg/cm^2, and the cushion material has a thickness between 7 mm and 50 mm, in which process the surface of the basic lining which contacts molten metal is heated to at least 500°C before the casting vessel receives the molten metal.

2. A process as claimed in Claim 1 using a casting vessel wherein the backing layer is composed of backing refractories placed on a rear of the basic lining, and cushion material provided between the backing refractories and the iron shell.

3. A process as claimed in Claim 1 using a casting vessel wherein the backing is composed of cushion material placed on a rear of the basic lining, and backing refractories provided between the cushion material and the iron shell.

4. A process as claimed in any of Claims 1 to 3 using a casting vessel wherein the cushion material is a ceramic fiber.

5. A process as claimed in any of Claims 1 to 3 using a casting vessel wherein the cushion material is an insulating board.

6. A process as claimed in any of Claims 1 to 5 using a casting vessel wherein the cushion material has a compressive characteristic of 40 to 70% up to a pressure of 10kg/cm^2.

7. A process as claimed in any of Claims 1 to 5 using a casting vessel wherein the cushion material has a thickness not exceeding 50% of the thickness of the basic lining which has a thickness between 70mm and 300 mm.

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1601612 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

FIG. 1

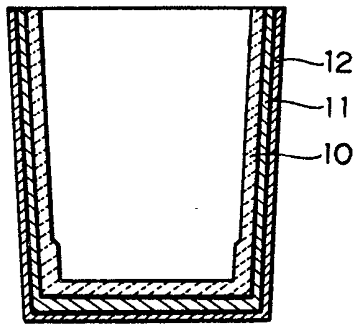


FIG. 2

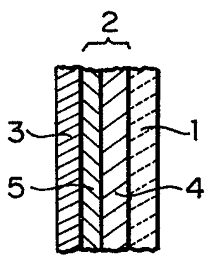


FIG. 3

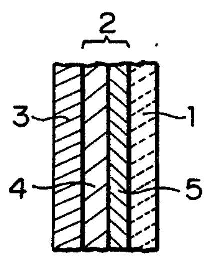


FIG. 4

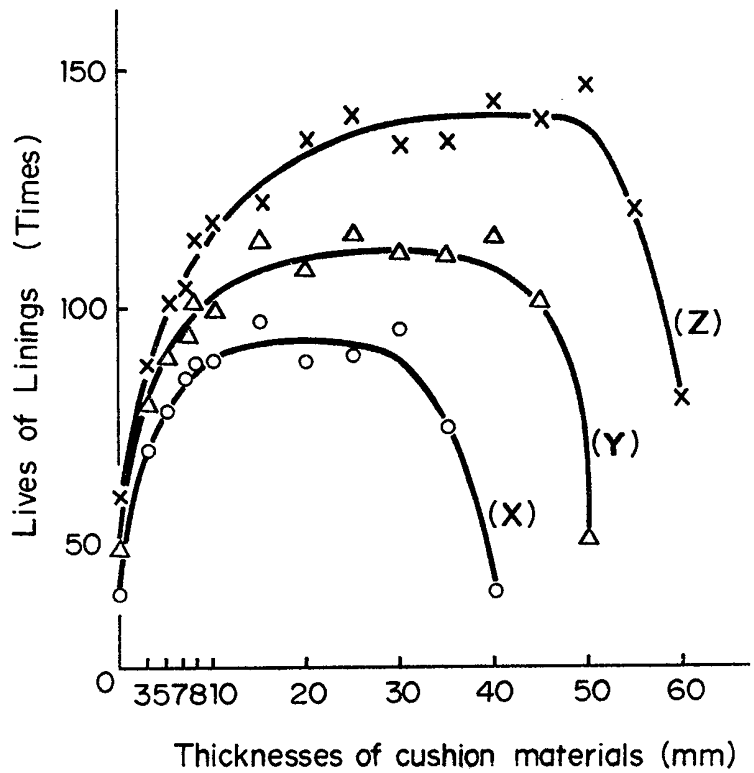

150
100
50
0
Lives of Linings (Times)
3 5 7 8 10
20
30
40
50
60
Thicknesses of cushion materials (mm)
(X)
(Y)
(Z)

FIG. 5

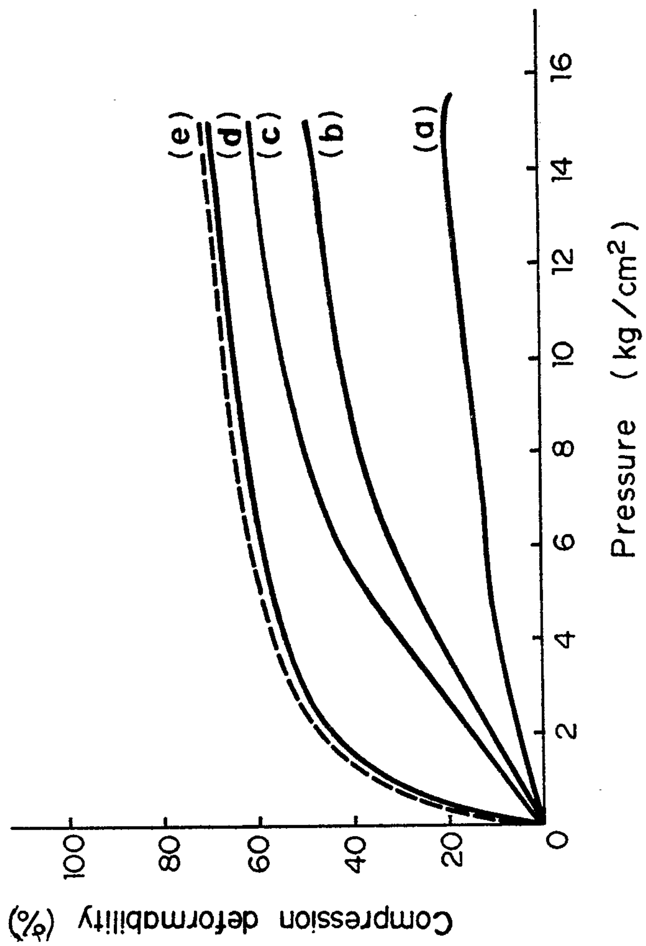
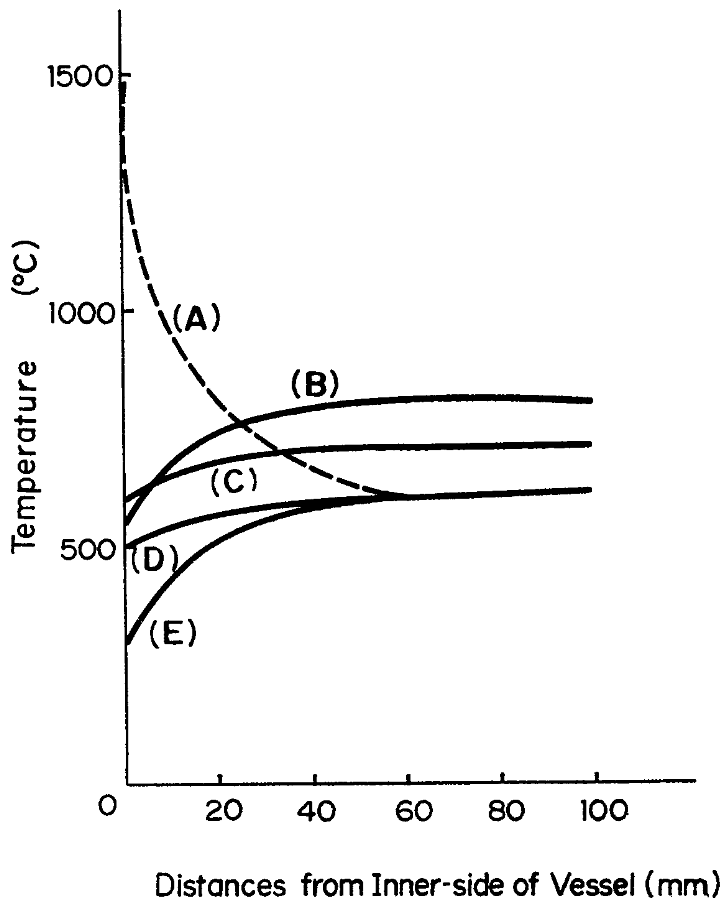

Compression deformability (%)
0
20
40
60
80
100
Pressure (kg/cm²)
2
4
6
8
10
12
14
16
(a)
(b)
(c)
(d)
(e)

FIG. 6


1500
1000
500
Temperature (°C)
(A)
(B)
(C)
(D)
(E)
0
20
40
60
80
100
Distances from Inner-side of Vessel (mm)