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(54) **METHOD FOR ENHANCING SELF-FEEDING ABILITY OF HEAVY SECTION CASTING BLANK**

(57) The present invention relates to the field of casting blank manufacturing, in particular to a method for enhancing the self-feeding ability of a heavy section casting blank, which can solve the problems of poor centre quality, surface crack and high rejection rate of the heavy section casting blanks in the prior art. By controlling the outer cooling conditions of different solidification stages of the casting blank, the present invention quickly solidifies and crusts the outer surface of the casting blank to increase the strength and prevent surface crack at first, and then performs thermal insulation on the casting blank surface such that large area of the core forms the mushy region such that the solidified layer of the casting blank surface is maintained at a relatively high temperature to

facilitate realization of the plastic deformation, thus realizing synchronous solidification and solid movement in the subsequent solidification and shrinkage processes of the casting blank, fulfilling the aim of radial self-feeding of the high-temperature deformable metal, eliminating the inner shrinkage voids and surface crack, and obviously eliminating the inner shrinkage of the casting blank. The present invention is applicable to the heavy section metal castings, in particular to the round and square heavy section casting blanks which have a large height-diameter ratio and cannot eliminate the axis shrinkage pipe through the feeder head.

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Description**BACKGROUND OF THE INVENTION****1. Technical Field**

[0001] The present invention relates to the fields of manufacturing of casting blanks, such as wide and thick metal slabs, round/square/rectangular heavy section casting blanks, and in particular to a method for enhancing the self-feeding ability of a heavy section casting blank, and eliminating the shrinkage voids and the surface cracks of the casting blank.

2. Description of Related Art

[0002] Wide and thick slabs (special slabs) have been widely applied in economic construction. A great amount of wide and thick slabs are used in large-sized ships, ocean platforms, hydroelectric generating sets, thermal power generating units, pressure containers, dies, and long-distance pipelines. Therefore, there are huge demands on thick-large section wide and thick slabs for rolling the wide and thick plates. At present, the maximum thicknesses of the continuous casting slabs all are smaller than 400mm. If the continuous casting slabs are adopted to roll the wide and thick plates with a thickness of 200mm, it is difficult to ensure the performance of the core due to a small reduction ratio. The mold casting method or electroslag remelting method for producing the wide and thick slabs has the disadvantages of low productivity, low success ratio, and high cost. So, it is urgent to develop a low-cost and high-efficiency technology for manufacturing wide and thick slabs with a thickness of over 600mm. Water-cooling molded wide and thick slab manufacturing technology is a quick one. However, when the water-cooling molding method is used to produce the wide and thick slabs, the large water-cooling intensity easily causes large temperature difference between the centre and the surface of the wide and thick slab, large thermal stress during solidification, and cracks in the surface and core of the slab.

[0003] The heavy section round continuous casting blank is used for replacing the common molded steel ingots, which shows a good development trend due to high production efficiency and high material utilization ratio. The heavy section casting blank can be used for producing nuclear torches, wind-power rings, and bond axis type of parts related to vehicles, ships and machines. In recent years, the continuous casting technology has been more and more applied in production of the heavy section casting blanks. This technology is as follows: continuously pour the liquid metal into a water cooling crystallizer, solidify the liquid steel in the water cooling crystallizer, and continuously cast the solidified part out from the lower end through a dummy bar to realize continuous casting of the blanks. This technology also has defects: the height-diameter ratio of the casting blank produced by this technology is large, so realization of axis feeding of the casting blanks is difficult, and it is easy to cause shrinkage and porosity of the centre of the cast blanks; moreover, the outer surface of the blank is usually processed with a forced-cooling process, which causes an extremely low temperature to the outer surface and results in cracks. Those defects limit the development of the round continuous casting blanks to the bigger section size ($\geq \Phi 800\text{mm}$).

[0004] The square and rectangular heavy section continuous casting blanks with a thickness of over 400mm also have the macro defects of inner shrinkage, porosity, and surface cracks.

[0005] Generally speaking, to overcome the defect of the inner shrinkage and porosity of the blank, a larger feeder head or a thermal-insulating (heating) feeder head is adopted to realize sequential solidification of the blanks along the gravity direction. However, the feeder head ratio of the heavy section continuous casting blank is very small, and the height-diameter ratio thereof is bigger than 4, so the axial gravity feeding of the casting blank cannot be realized.

[0006] In conclusion, the inner shrinkage, porosity, and surface cracks of the heavy section casting blanks are technical bottlenecks that limit the development of the casting blanks towards the bigger section sizes. Thus, enhancing the feeding ability of the heavy section casting blanks in the solidification process is of key importance for overcoming the defects of the inner shrinkage and porosity and surface crack of the heavy section casting blanks.

BRIEF SUMMARY OF THE INVENTION

[0007] The aim of the present invention is to provide a method for eliminating the centre shrinkage, porosity, and surface cracks of heavy section molded wide and thick slabs and round and rectangular continuous casting blanks through enhancing the self-feeding ability of the heavy section casting blank. Therefore, it is beneficial to develop technologies for manufacturing round casting blanks with a diameter of over 500mm and square or rectangular casting blanks with a thickness of over 400mm.

[0008] To fulfill the aim, the present invention adopts the following technical scheme:

A method for enhancing the self-feeding ability of a heavy section casting blank comprises these steps: after pouring the liquid metal, immediately forced-cooling the outer surface of a casting blank by means of molded water cooling,

direct water spraying, fog spraying or blowing to rapidly solidify it; when the temperature of the outer surface of the casting blank is reduced to 800~1000°C and the thickness of the solidified layer reaches 5-30% of the thickness or diameter of the blank section, stop forced-cooling the outer surface.

[0009] In accordance with the method for enhancing the self-feeding ability of a heavy section casting blank, when the thickness of the solidified layer reaches 50-300mm, stop forced-cooling the outer surface of the casting blank.

[0010] In accordance with the method for enhancing the self-feeding ability of a heavy section casting blank, control the cooling conditions of the outer surface of the casting blank to keep the outer surface of the casting blank at a temperature of 200~400°C below solidus, which makes the solidified layer of the outer surface of the casting blank stay in the plastic deformation region with a low deformation resistance.

[0011] In accordance with the method for enhancing the self-feeding ability of a heavy section casting blank, after stopping forced-cooling the outer surface of the casting blank, use a thermal insulating material or a heat cover to insulate the outer surface of the casting blank to reduce the intensity of heat exchange between the outer surface of the casting blank and the environment; then the temperature of the outer surface of the casting blank rises because of the latent heat in the casting blank core which reducing the radial temperature gradient of the casting blank, and then the core of the casting blank forms the mushy region and is solidified synchronously.

[0012] In accordance with the method for enhancing the self-feeding ability of a heavy section casting blank, when the liquid metal of the core is solidified synchronously, solidification and shrinkage generate a radial tensile stress which is acted on the high-temperature solidified layer of the outer surface, so the solidified metal generates plastic deformation and plastically moves from the outer surface to the blank centre, thus realizing radial self-feeding of the casting blank.

[0013] In accordance with the method for enhancing the self-feeding ability of a heavy section casting blank, after the core of the casting blank is solidified synchronously and the radial self-feeding is realized, the casting blank surface and the casting blank core are still in the high temperature state; at this time, de-mold at the high temperature, wherein the de-molding temperature required by the casting blank is higher than 800°C.

[0014] In accordance with the method for enhancing the self-feeding ability of a heavy section casting blank, the de-molding temperature required by the casting blank is preferably 850-1, 200°C.

[0015] The method for enhancing the self-feeding ability of a heavy section casting blank is applicable to square or rectangular casting blanks with a thickness of over 400mm, round casting blanks with a diameter of over 500mm, and molded wide and thick slabs with a thickness of over 600mm.

[0016] The present invention has the following advantages:

1. Traditionally, the casting blanks usually perform axial feeding along the gravity direction; the present invention realizes the radial self-feeding in a direction vertical to the gravity direction during the solidification of the casting blanks by controlling the outer cooling conditions of the casting blanks.

2. In the initial stage of the solidification of the heavy section casting blanks, the present invention adopts a water cooling, fog cooling or air cooling means to enhance the coefficient of heat exchange between the casting blank and the outside to rapidly solidify blank surface, thus fast increasing the casting blank surface strength and preventing thermal cracks generated because of thin solidified layer of the casting blank surface and low strength in the initial stage of solidification.

3. In the present invention, when the thickness of the solidified layer of the casting blank reaches 5-30% (usually 5-300mm) of the diameter or thickness of the section, stop forced-cooling the outer surface of the casting blank; at this time, the solidified outer layer is at a low temperature, which provides a low-temperature external environment for the region of the casting blank core that is not solidified, guarantees the solidification speed of the liquid metal of the core, and avoids excessively big crystal particles of the core.

4. In the middle and rear stages of solidification of the casting blank, the present invention performs thermal insulation on the casting blank surface such that the temperature of the casting blank surface rises to stay in the plastic region, which is good for preventing the casting blank surface from cracking due to relatively thermal stress.

5. In the middle and rear stages of the solidification of the casting blank, the present invention performs thermal insulation on the casting blank surface, which can reduce the temperature gradient of the heavy section casting blank from the inside to the outside, enables the large area of the blank centre to form the mushy region synchronously, realizes synchronous solidification of the blank centre, and avoids generation of the centralized defects of the shrinkage voids.

6. By the method provided by the present invention, when the large area of the blank centre is synchronously solidified the radial tensile stress generated by solidification and shrinkage drives the high-temperature solid metal which has been solidified on the outer surface of the casting blank to plastically move from the casting blank surface to the centre, thus realizing the radial self-feeding during the solidification of the casting blank, and eliminating the defect of inner shrinkage and porosity of the casting blank.

7. The method provided by the present invention fully maximizes the radial self-feeding ability of the heavy section

casting blank, which can reduce the feeder heat size of the casting blank and further improve the material utilization ratio of the heavy section casting blank.

8. The present invention can be applied in a large scope and can be used for producing round, square or rectangular heavy section casting blanks, molded wide and thick slabs, and other heavy section castings.

9. The method provided by the present invention also can realize blank high-temperature de-molding and hot charging, improve the production efficiency, and saves energies.

[0017] All in all, by controlling the outer cooling conditions of different solidification stages of the casting blank, the present invention quickly solidify and crust the outer surface of the casting blank to increase the strength and prevent surface crack at first, and then perform thermal insulation on the casting blank surface such that large area of the core forms the mushy region and that the solidified layer of the casting blank surface is maintained at a relatively high temperature to facilitate realization of the plastic deformation, thus realizing synchronous solidification and solid-phase movement in the subsequent solidification and shrinkage processes of the casting blank, fulfilling the aim of radial self-feeding of the high-temperature deformable metal, eliminating the inner shrinkage and surface crack of the casting blank, obviously eliminating the inner shrinkage of the casting blank. Meanwhile, the method can realize hot charging of the casting blank, improve the production efficiency, and fulfill the aim of saving energies. The present invention is applicable to the heavy section metal castings, in particular to the round and square heavy section casting blanks which have a large height-diameter ratio and cannot eliminate axis shrinkage pipe through the feeder head.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0018]

Figure 1 shows a water-cooling molded wide and thick slab produced by the present invention.

Figure 2 shows a round heavy section casting blank produced by the present invention, wherein, figure 2(a) shows a real round heavy section casting blank, and figure 2(b) shows the cross section of the round casting blank.

Figure 3 shows a round casting blank which is not produced by the prevent invention and has shrinkage voids in the centre, wherein, figure 3(a) shows a real round heavy section casting blank, and figure 3(b) shows the cross section of the round casting blank.

DETAILED DESCRIPTION OF THE INVENTION

[0019] The present invention provides a method for eliminating inner shrinkage, porosity and surface cracks by enhancing the self-feeding ability of a heavy section casting blank, comprising the following steps:

1. Adopt melting equipment such as the electric induction furnace or electric arc furnace to melt liquid steel, and then perform deoxidization and degassing.

2. Pour the melt liquid steel into a wide and thick slab molding casting chamber or continuous casting crystallizer.

3. Force-cool the outer surface of the casting blank by the water cooling mold or crystallizer to rapidly solidify the casting blank surface, or strengthen heat exchange between the casting blank and the environment by means of water spraying, fog spraying or air blowing.

4. In the process of forced-cooling of the casting blank surface, monitor and measure the temperature of the casting blank surface by a contact or non-contact type temperature measuring device, and control the temperature of the casting blank surface to be 800~1, 000°C as far as possible. Prevent an extremely low temperature, otherwise cracking will be caused because the solidified metal generates solid-state phase change and structural stress; meanwhile, avoid high temperature, otherwise, the solidified layer will be thin and has low strength, and the casting blank surface "bulges" under the static pressure of the liquid metal and generate cracks.

5. After the thickness of the solidified layer of the casting blank reaches 50-300mm, stop forced-cooling the casting blank surface, and perform thermal insulation on the casting blank surface. When the temperature of the casting blank surface rises continuously, monitor and measure the temperature of the outer surface, and adjust the intensity of heat exchange between the casting blank and the environment by means of measures such as thermal insulation or cooling, and then the temperature of the casting blank surface is kept in a plastic deformation region with a temperature of 200~400°C below the material solidus.

6. The temperature gradient between the blank centre and the outer surface gradually decreases, and the large area of the blank centre forms the mushy region. In the subsequent cooling process, the blank centre is solidified synchronously; a tensile stress is generated because of the solidification and shrinkage, which promotes the solidified solid-state metal on the outer surface of the casting blank to generate plastic deformation and plastically move from the casting blank surface to the centre, thus realizing the radial self-feeding during the solidification of the casting

blank.

Embodiment 1

[0020] In this embodiment, the method provided by the present invention is adopted to produce the molded wide and thick slab; the material of the wide and thick slab is Q345; the thickness of the wide and thick slab is 1,000mm, and the total mass is 60 tons.

[0021] An electric arc furnace is used to melt the liquid steel; then the liquid steel is refined in an LF furnace and next poured into the VD furnace for deoxidization and degassing. At a temperature of 1,560°C, the liquid steel is poured into a separated water-cooling mold in a total time period of 30 min. Through stimulation and calculation, it is known that the thickness of the solidified layer of the surface of the wide and thick slab is 90mm 40min after pouring. At this time, reduce the water flow of the water-cooling mold and increase the gap between the mold and the wide and thick slab to reduce the speed of heat dissipation on the surface of the wide and thick slab. By monitoring the temperature change on the surface of the wide and thick slab, it is found that the surface temperature of the wide and thick slab rises from 920°C to 1,100°C-1,250°C and then the casting blank is gradually cooled until totally solidified. After the casting blank is completely solidified, de-mold at a high temperature of 900°C, and slowly cool after de-molding with a speed controlled to be 30-40°C/h.

[0022] Figure 1 shows a wide and thick slab produced in this embodiment. Through non-destructive inspection, it is found that the slab has no defect of inner shrinkage void and surface cracks.

Embodiment 2

[0023] In this embodiment, the method provided by the present invention is adopted to produce the heavy section round continuous casting blank; the material of the round blank is 20CrNi2Mo; the diameter is 1,000mm; the length is 8m; and the total mass of the round blank is 45 tons.

[0024] Pour the melted liquid steel into a crystallizer at a temperature of 1,540°C, wherein the casting speed of the blank is 0.1m/min. By stimulation and calculation, it is found that the solidified layer of the surface is about 50mm thick and the surface temperature is about 850°C when the blank is dragged out from the crystallizer. Once the blank is cast out of the crystallizer, perform thermal insulation on the casting blank surface with a thermal insulation material such as the asbestos cloth; and then the temperature of the casting blank surface rises to 1,200-1,260°C, reaching the plastic region. The temperature gradient of the casting blank reduces from the inside to the outside to realize the synchronous solidification of the central area. In the subsequent cooling process, the outer surface of the casting blank generates plastic deformation, and the solid generates contraction and movement from the outside to the inside, thus realizing radial self-feeding.

[0025] Figure 2(a) shows the heavy section round casting blank produced by the technology of the present invention in this embodiment. Through non-destructive inspection, it is found that the blank has no inner shrinkage void and the casting blank surface has no cracking defect. Figure 2(b) shows the cross section of the round blank without centralized shrinkage voids in centre and with a porosity level of below 2.

[0026] Figure 3(a) shows the round casting blank which is not produced by the technology provided by the present invention and has the same size and specification. The centre of the round blank has shrinkage voids in a large area and the porosity defect, as shown in figure (3b).

[0027] The results show that, by controlling the outer cooling conditions of the different solidification stages of the blank, the present invention enables a large area of the blank centre to form the mushy region and meanwhile maintains the solidified layer of the casting blank surface at a relatively high temperature, thus realizing the plastic movement of the solid phase in the subsequent solidification processes, fulfilling the aim of radial self-feeding of the high-temperature deformable metal, eliminating the inner shrinkage and porosity of the casting blank, and preventing surface crack.

[0028] The defect levels before and after the $\Phi 800$ -1,200mm round blank processed in the above embodiment is subject to the detection processing in accordance with YB/T 4149-2006 can be seen in table 1.

Table 1

	Centre porosity	Centre shrinkage	Centre cracks	Surface cracks
Before processing	Level 3-4	Level 2-3	Level > 4	Few
After processing	Level 0-1	No	Level 0-1	No

Claims

1. A method for enhancing the self-feeding ability of a heavy section casting blank, **characterized by:** after metal pouring, immediately force-cooling the casting blank surface to quickly solidify and crust the casting blank surface; then, performing thermal insulation on the casting blank surface with a thermal insulation material or a heat cover for reducing the intensity of heat exchange between the casting blank surface and the environment; raising the temperature of the casting blank surface by latent heat in the casting blank core and reducing the radial temperature gradient of the blank to enable the casting blank core to form a large mushy region synchronously and promote the synchronous solidification of the casting blank core; when the casting blank core is solidified synchronously, the casting blank surface is still in a high temperature state, enhancing the self-feeding ability by the action of the tensile stress generated by solidification and shrinkage of the core; after the casting blank core is completely solidified, de-molding at a high temperature, and then performing slow cooling or high-temperature annealing.
2. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 1, **characterized in that**, after pouring the liquid metal, immediately forced-cooling the outer surface of a casting blank by means of water cooling, direct water spraying, fog spraying or blowing; when the temperature of the outer surface of the casting blank is reduced to 800~1000°C and the thickness of the solidified layer reaches 5-30% of the thickness or diameter of the blank section, stopping forced-cooling the outer surface.
3. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 1 or 2, **characterized in that**, when the thickness of the solidified layer reaches 50-300mm, forced-cooling of the outer surface of the casting blank is stopped.
4. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 1, **characterized in that**, controlling the cooling conditions of the outer surface of the casting blank to keep the outer surface of the casting blank at a temperature of 200~400°C below solidus, so the solidified layer of the outer surface of the casting blank stays in the plastic deformation region with a low deformation resistance.
5. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 1, **characterized in that**, when the liquid metal of the core is solidified synchronously, solidification and shrinkage generate a radial tensile stress which is acted on the high-temperature solidified layer of the outer surface, so the solidified metal generates plastic deformation and plastically moves from the outer surface to the casting blank centre, thus realizing radial self-feeding of the casting blank.
6. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 1, **characterized in that**, for high-temperature de-molding, the de-molding temperature required by the casting blank is bigger than 800°C .
7. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 6, **characterized in that** the de-molding temperature required by the casting blank is preferably 850-1, 200°C.
8. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 1, **characterized in that** the slow cooling is performed after the casting blank is de-molded at a high temperature, and the cooling speed is smaller than 50°C/h.
9. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 8, **characterized in that** the cooling speed is preferably 10-30°C/h.
10. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 1, **characterized in that** after the casting blank is de-molded, the high-temperature annealing temperature is bigger than 800°C, preferably 850-1100°C; and the annealing cooling speed is smaller than 50°C /h.
11. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 10, **characterized in that** the annealing cooling speed is preferably 10-40°C/h.
12. The method for enhancing the self-feeding ability of a heavy section casting blank according to claim 1, **characterized**

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in that the method is applicable to square or rectangular continuous casting blanks with a thickness of over 400mm, round continuous casting blanks with a diameter of over 500mm, and molded wide and thick slabs (special slabs) with a thickness of over 600mm.

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FIG. 1

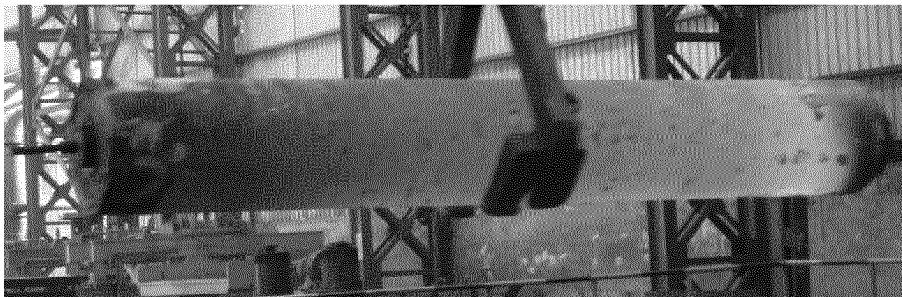


FIG. 2(a)



FIG. 2(b)



FIG. 3(a)

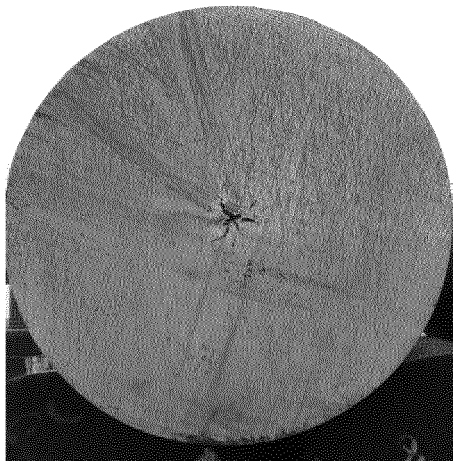


FIG. 3(b)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2011/076640

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B22D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC, CNKI, CNPAT: heavy, large, thick, section, cross, feed, cool, heat, preserve, insulate, thermal, quick, forced, core, liquid, melt, molten, slow, gradient, latent, solidify, crack, shrinkage, porosity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN101823133A (NOVELIS INC) 08 Sep. 2010 (08.09.2010) See paragraphs 26-35 and paragraphs 91-133 of description, figures 1-4	1-12
X	US2705353A (Zeigler) 05 Apr. 1955 (05.04.1955) See column 1, line 39-column 3, line 64 of description, figures 1-5	1-12
A	CN101758208A (SHANGHAI HONGGANG POWER EQUIP CASTING & FORGING CO LTD) 30 Jun. 2010 (30.06.2010) See the whole document	1-12

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
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INTERNATIONAL SEARCH REPORT
 Information on patent family members

International application No.

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US2705353A	05.04.1955	None	
CN101758208A	30.06.2010	None	

Form PCT/ISA /210 (patent family annex) (July 2009)

INTERNATIONAL SEARCH REPORT

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Continuation of: second sheet A. CLASSIFICATION OF SUBJECT MATTER

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