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(54) Apparatus and method for temperature control of cast products

(57) The present invention discloses an apparatus and a method for temperature control of a cast product (1), wherein said apparatus is designed for being mounted downstream a mould (2) for casting and comprises:

- a heating system (3) comprising at least one reflecting hood (31, 32, 33, 34), each reflecting hood being designed for covering solely a peripheral part (11) of the cast product (1) which is, during casting, farthest from the hottest part (12) of said cast product (1) in its cross section;
- a cooling unit capable of overcooling the surface of the cast product (1).

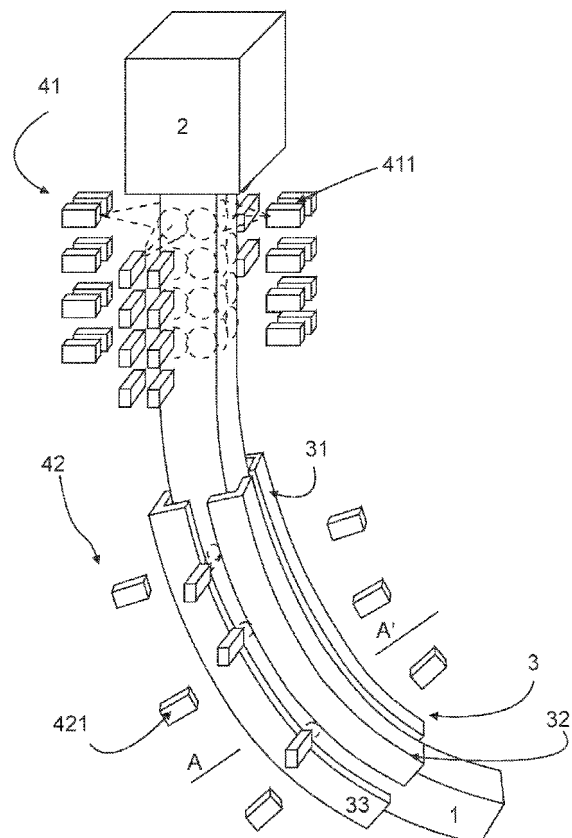


FIG 1

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Description

[0001] The present invention relates to an apparatus and a method for controlling the temperature of metal elongated long products manufactured in a continuous casting plant.

[0002] The production of metal elongated long products is realized in a casting plant by successive steps. First, metallic scraps are provided as feeding material to a furnace which heats the scraps up to reaching molten metal. Afterwards, the molten metal is continuously poured into a mould for continuously manufacturing a metal product, for example a billet, which size is defined by the mould. Said mould generally comprises a cooling system for enhancing and controlling the solidification of the molten metal, by increasing the thickness of the solid skin that shapes the metal product. Finally, the product might be then directly used to feed a rolling mill (direct rolling or endless rolling), or stocked as feeding material for a next rolling.

[0003] A main problem when cooling down a metal product in continuous casting is that depending on the shape of the product, the surface temperature of said product will not be uniform when cooling down. For example, if the product has a round shape, the surface will cool down sensibly uniformly, while for a square shape, the corners cool down faster than the center of the surface (between said corners). This is due to the fact that the cast product is subject to forced cooling, and due to the multidirectional heat transfer typical of corner area, the temperature is lower in said corner area. As result, the solidification of the corners occurs more rapidly than the solidification on flat surfaces between said corners. The non uniform distribution of temperature on the surface of the metal product can create defects, like cracks on the surface and inside said product (for example longitudinal corner cracks), which decrease the product quality and may effect the use of said product as feeding material, for example in a rolling mill. Especially in process like direct rolling or endless rolling, where the casting product is directly sent to the rolling line, these defects may be sources of important time and economical lost, since it is not possible to check the quality of the cast product in advance and eventually to apply correction before it becomes rolled by the rolling mill. In this case, the defects of the metal product can create rolling defects due to different spread effect during deformation with additional cracks or with differences in final mechanical properties in the product section.

[0004] Various techniques have been used to try uniformizing the surface temperature of the cast product, for example by heating the corner of a rectangular-section cast product by an active heating systems capable of making the cast product recover a temperature level suitable to rolling mill (1000-1100 °C) or by cooling its faces between said corners with local water spray. But these techniques are generally expensive in material and in energy, and are not efficient enough for reducing the

number of cracks. For instance in the direct feed process of a rolling mill by cast product, an induction furnace is sometimes used at the entrance of said mill to recover the temperature difference between face and corners. Such induction furnace needs a high electrical power and gives rise to high operating costs. In standard rolling mill the induction furnace is normally replaced by a re-heating furnace. When temperature differences already originated in "as cast" products quality defects (cracks), then the problem can only be solved either by completely discarding the affected product, or by grinding/scarfing it, with consequent yield loss.

[0005] An objective of the present invention is to propose an apparatus and a method for preventing or reducing defects (e.g. cracks) appearing in a cast product during its solidification phase, said apparatus and method having to be simple, economically attractive, and characterized by a low energy consumption.

[0006] The objective is achieved according to the present invention with respect to the apparatus by an apparatus for controlling the temperature of an elongated cast product, said apparatus, designed for being mounted downstream a mould for casting cast products of a continuous casting machine, comprising:

- a heating system comprising at least one reflecting hood, which can be in particular either movable or in a fixed position, each reflecting hood being designed for covering solely a peripheral part of the cast product which is farthest from the hottest part of said cast product in its cross section during casting (e.g. each reflecting hood of a four reflecting hoods heating system cover a different corner of a four corners square section cast product), so that each of said peripheral parts is covered by at least one reflecting hood, each reflecting hood being in particular capable of accumulating radiated heat energy from the cast product and of transmitting, notably by reflection and/or emission, said radiated heat energy to a specific zone of the cast product, wherein said specific zone is a surface of said cast product whose cooling rate is higher than other surfaces of the cast product. Therefore, said specific zone might have for example a surface temperature that is between 50°C and more than 200°C lower than other parts of the cast product surface;
- a cooling unit capable of overcooling the surface of the cast product, wherein said cooling unit comprises in particular a first cooling system and a second cooling system, wherein the first cooling system is designed for cooling the whole surface of the cast product immediately downstream the mould of the continuous casting machine producing said elongated cast product and is positioned before said heating system, and said second cooling system is positioned downstream the first cooling system, before or together with said heating system and is designed for cooling the hottest part of each face of said cast

product;

- and preferentially, a moving system capable of displacing each reflecting hood of said heating system, wherein said moving system is in particular capable of increasing, respectively decreasing, the distance between one extremity of the reflecting hood and the cast product, notably according to heat transfer calculation and solidification/temperature curves.

[0007] The objective is achieved according to the present invention with respect to the method by a method for controlling the temperature of an elongated cast product, downstream a mould for casting cast products of a continuous casting machine, said method comprising the following steps:

- a cooling of the surface of the cast product, in particular a cooling of the whole surface of the cast product immediately downstream the mould by means of a first cooling system of a cooling unit;
- a controlled heating of a specific zone of the cast product, wherein said specific zone is a surface of said cast product whose cooling rate is higher than other surfaces of the cast product, wherein said heating is realized by a reflecting hood of a heating system, wherein each reflecting hood is able to accumulate radiated heat energy from the cast product and to transmit, notably by emission and/or reflection, said radiated heat energy back to at least one of said specific zone of the cast product;
- and preferentially, a cooling of the hottest part of each face of the cast product by means of a second cooling system of said cooling unit, wherein said second cooling system is positioned downstream the first cooling system, before or together with said heating system.

[0008] The present invention proposes also a continuous casting machine for producing said elongated cast product, said continuous casting machine comprising means for producing liquid metal, means for continuous casting an elongated cast product from said liquid metal, wherein the means for continuous casting comprise a mould having in particular a plurality of corners and drawing means for drawing the cast product out of the mould, the continuous casting machine being characterized in that it comprises the previously described apparatus for controlling the temperature of said elongated cast product. In particular, said mould might be a cooled mould comprising a cooling system for cooling the liquid metal so that the surface of the elongated product is solid at the exit of said mould. Preferentially, the reflecting hood of the claimed apparatus is positioned after the mould, preferentially in a section wherein the elongated cast product follows a curvilinear trajectory, before any deformation means designed for deforming the elongated product.

[0009] According to the present invention, each peripheral

part of the cross section of the cast product which is farthest from the hottest part of said cross section of the cast product during casting may be covered by one or several reflecting hoods, but each reflecting hood is designed for covering a single peripheral part of the cross section of the cast product, wherein each reflecting hood is positioned over said single peripheral part, and might be extended longitudinally along the trajectory followed by said single peripheral part during casting. In other words, each reflecting hood is thus a cover for said peripheral part, wherein the distance between the peripheral part and the reflecting hood might be preferentially adapted in function of the type of the cast product and its physical properties, for example by means of the moving system capable of displacing one or several reflecting hoods closer or farther from the elongated cast product. Indeed, the method according to the present invention comprises in particular adjusting the covering of each peripheral part of the cast product which is, during casting, farthest from the hottest part of said cast product in its cross section, by moving said reflecting hood.

[0010] Preferentially, the number of reflecting hoods equals the number of peripheral parts of the cast product which are, during casting, the farthest from the hottest part of said cast product in its cross section. Preferentially, each reflecting hood is axially extended along the length of said elongated cast product and might have for example but not only a transverse section characterized by a parabolic shape or an L shape. Advantageously, the shape of the transverse section of the reflecting hood allows to concentrate the radiated heat that has been accumulated and/or reflected in one or more specific zones of the cast product. For example, the reflecting hood can be made of INCONEL alloy, wherein INCONEL refers to a series of special alloys notably based on Ni and containing up to 70% of Ni and up to 30% Cr according to what alloy of the series is used. INCONEL has a high resistance to high temperature and corrosion, and high reflecting properties. Similar or other alloys capable, as the INCONEL, of using internal heat of the cast product to reheat the cast product itself, notably by reflection of the radiated energy, might be used. Preferentially, each hood is laterally extended in order to cover between 10% and 30% of the cast product lateral dimension, and the hood length (i.e. its dimension along the length of the elongated cast product) might be adapted to the type of cast product. Preferentially, the transverse section shape of the reflecting hood might also be adapted to the cast product section shape and material. In particular, different reflecting hoods might be used with the same moving system for controlling the energy exchanges between the cast product and the reflecting hood.

[0011] According to a preferred embodiment, the moving system is capable of increasing, respectively decreasing, the distance between one extremity of the reflecting hood and a surface of the cast product, while decreasing, respectively increasing, the distance between another extremity of the reflecting hood and another

other surface of the cast product. In other words, a reflecting hood may not be parallel to the length of the extended cast product, but may have one extremity closer to the cast product, while the other extremity may be farther from said cast product in order to control the quantity of heat that is provided by the reflecting hood to the cast product. Thus, the present invention allows a control of the quantity of heat supplied by the heating system by means of an adjustment of the position of each reflecting hood relative to the surface of the cast product preferentially in function of a heat transfer calculation and solidification/temperatures curves of the cast product. According to another preferred embodiment, the claimed apparatus comprises a system for measuring and analysing the surface temperature of the cast product, wherein said system comprises at least one temperature detector (for example a camera, like an IR-camera) positioned immediately downstream the heating system and is capable of commanding the moving system in function of a measured surface temperature value of the cast product. Preferentially, a plurality of detectors of said system allows to measure the temperature of the whole periphery of a transverse section of the cast product. Advantageously, a change of the position of each reflecting hood might be automatically commanded by the system for measuring and analysing the surface temperature in function of the measured surface temperature according to a feedback loop. In other words, the present invention proposes in particular a measurement of the surface temperature of the cast product immediately downstream the heating system and adjusting the position of each reflecting hood relative to the surface of the cast product in function of the measured temperature.

[0012] Preferentially, the first cooling system and the second cooling system comprise each at least one spray for spraying the cast product surface with a cooling liquid, which is for example water or a mixture of water and air, for enhancing the solidification of the cast product and reducing its solidification time. In particular, the cooling capacity of the first cooling system is higher than the cooling capacity of the second cooling system. For example, the first cooling system comprises a number of sprays that is greater than the number of sprays of the second cooling system, wherein each spray has in particular an identical flow which can notably be tuned by the system for measuring and analysing in function of surface temperature measurement. Preferentially, the number of sprays of the first cooling system is chosen so that the sprayed surface is the whole surface of the cast product for a length that is determined in function of the dimension of the cast product, the casting speed and the cast material. The number of sprays of the second cooling system is in particular chosen so that they achieve a predetermined spraying rate calculated in function of the dimension of the cast product, the casting speed and the cast material, and so that only surfaces that are or will not be covered by the heating hood are sprayed, i.e. in other words, each central zone of each face of the cast product,

wherein said central zone comprises the peripheral part of the cast product which is, during casting, the closest to the hottest part of said cast product in its cross section. Preferentially, each spray is able to spray according to different patterns, using different cooling media, such as a cooling liquid capable of cooling the surface of the cast product.

[0013] The structural and functional characteristics of the invention and its advantages with respect to the known art will be further described with reference to exemplary embodiments illustrated in the enclosed drawings:

Figure 1 schematic illustration of the apparatus for controlling the temperature of an elongated cast product according to the present invention.

Figure 2 schematic illustration of a parabolic reflecting hood according to the invention.

[0014] Figure 1 shows a preferred embodiment of an apparatus for controlling the temperature of an elongated cast product

1 according to the invention. Said apparatus is in particular designed for being mounted downstream a mould 2 of a continuous casting machine for casting said cast product 1, said apparatus comprising:

- a heating system 3 comprising at least one reflecting hood 31, 32, 33, 34, which can be in particular either movable or in a fixed position, each reflecting hood 31, 32, 33, 34 being designed for covering solely a peripheral part 11 of the cast product 1 which is farthest from the hottest part 12 of said cast product in its cross section during casting. Each peripheral part of the cast product 1 is therefore temporarily covered by the reflecting hood, wherein the time during which the peripheral part of the cast product is covered by the reflecting hood depends on the casting speed and of the length of said reflecting hood along the cast product trajectory. For a square section cast product 1, four reflecting hoods 31, 32, 33, 34 may in particular each cover one of the four corners of the square section cast product 1. Each reflecting hood 31, 32, 33, 34 is able to accumulate radiated heat energy from the cast product 1 and of transmitting, notably by reflection and/or emission, said radiated heat energy to a specific zone of the cast product, e.g. to the corner surface of the square section cast product, wherein said specific zone is a surface of said cast product whose cooling rate is higher than other surfaces of the cast product;
- a cooling unit capable of overcooling the surface of the cast product, wherein said cooling unit comprises a first cooling system 41 and a second cooling system 42, wherein the first cooling system 41 is designed for cooling the whole surface of the cast prod-

uct immediately downstream the mould 2 of the continuous casting machine producing said elongated cast product 1 and is positioned before said heating system 3, and said second cooling system 42 is positioned downstream the first cooling system 41, before or together with said heating system 3 and is designed for cooling the hottest part of each face of said cast product;

- and preferentially, a moving system capable of displacing each reflecting hood of said heating system, wherein said moving system is in particular capable of increasing, respectively decreasing, the distance between one extremity of the reflecting hood and the cast product, notably according to heat transfer calculation and solidification/temperature curves. In particular, each reflecting hood might be coupled to said moving system by means of holding points allowing an automatic or a manual change of the reflecting hood position, depending for example on differences of cast product sections. According to a preferred embodiment, the moving system comprises at least one cylinder or piston (hydraulic or pneumatic) that is able to actuate a lever attached to the reflecting hood for allowing its positioning. By means of said cylinder or piston, each reflecting hood has three degree of freedom which allows a precise positioning of the reflecting hood in function of measurements and analysis of cast product surface temperature by means of a system for measuring and analysing the surface temperature, which comprises for example a set of IR cameras able to image the whole surface of a predefined length of cast product after the heating system.

[0015] The reflecting hood 31, 32, 33, 34 comprises in particular a reflecting surface 301 designed for being directed towards the cast product and capable of reflecting the radiated heat energy to said specific zone, e.g. the corner surface of the cast product 1. Preferentially, the reflecting hood 31, 32, 33, 34 extends continuously or discontinuously along the cast product trajectory, covering at least the peripheral part 11 of the cast product 1, its lateral dimension allowing an opening 5 between two adjacent reflecting hoods. Said opening 5 advantageously allows either a passive cooling of the cast product hottest surfaces by heat exchange with the surrounding environment or preferentially an active cooling of said cast product hottest surfaces by means of the second cooling system 42, which is able to spray a cooling liquid on said hottest surface through the opening 5. Consequently, the hottest surfaces of a square section cast product might advantageously be overcooled with respect to the corners.

[0016] Preferentially, the lateral cross section of a reflecting hood 31, 32, 33, 34 according to the invention might have a L-shape as presented in Fig. 1, or a C-shape or parabolic shape as presented in Fig. 2. Each reflecting hood is in particular able to avoid a temperature

lost of peripheral parts of the cast product due to radiation, keeping in the meantime an internal heat radiated by the cast product concentrated on said peripheral parts, increasing thus the temperature of said peripheral parts compared to the temperature of a same cast product produced by a casting machine that does not comprise the reflecting hood according to the invention. The reflecting hood length in the vertical direction (i.e. its longitudinal length in the casting direction), as well as its position with respect to the cast strand, and its extension over the peripheral parts of the cast product (i.e. its lateral extension e.g. over the corner), are in particular determined by respective heat transfer calculation and solidification/temperature curves of cast products, according to requirements in terms of temperature and/or quality.

[0017] Preferentially, the first cooling system 41 comprises a series of sprays 411, disposed along the cast product trajectory and around said trajectory, in the top part of the casting machine (i.e. just after the mould 2), in order to be able to spray the whole surface of the cast product after it exits from the mould 2, for creating a solid shell for said cast product. Each face of the cast product might therefore be sprayed by means of one or several sprays facing the face.

[0018] Preferentially, the second cooling system 42 comprises a series of sprays 421, disposed along the cast product trajectory and around said trajectory, in the bottom part of the casting machine (i.e. after the first cooling system 41, but before any deformation of the cast product), and are in particular able to cooperate with the reflecting hoods 31, 32, 33, 34 for spraying surfaces of the cast product appearing through windows or opening 5 between adjacent reflecting hoods.

[0019] Finally, the method and the apparatus according to the invention have the following advantages:

- the reflecting hood according to the invention is not only able to maintain an average higher temperature of the cast product, but also to concentrate radiated heat energy on one or more specific zones of the cast product;
- the combination of a cooling unit and a heating system optimizes the control of temperature of the cast product and allows to homogenize the cast product surface temperature using internal and latent solidification heat, avoiding or minimizing a use of additional active systems for heating or cooling the cast product;
- the overall layout length between the mould and a rolling machine is shorter in case of direct rolling solution and compared to traditional casting machine, since according to the invention, no active re-heating system is necessary before rolling;
- the quality of the cast product is improved;
- due to the use of internal heat, no additional energy consumption is required, hence no production (direct or indirect) of additional CO₂ in the process;
- they allow to avoid excessive cooling of the product

in case of strand stoppages, i.e. the so called "Flying tundish" practice, which requires stop of the strand inside the machine for some minutes (5-15 minutes according section) during change of the casting tundish.

Claims

1. Apparatus for controlling the temperature of an elongated cast product (1), said apparatus designed for being mounted downstream a mould (2) for casting said cast product (1) comprising:
 - a heating system (3) comprising at least one reflecting hood (31, 32, 33, 34), each reflecting hood being designed for covering solely a peripheral part (11) of the cast product (1) which is, during casting, farthest from the hottest part (12) of said cast product (1) in its cross section;
 - a cooling unit capable of overcooling the surface of the cast product (1).
2. Apparatus according to claim 1, comprising a moving system capable of displacing each reflecting hood (31, 32, 33, 34) of said heating system (3) for increasing or decreasing the distance between said reflecting hood and the cast product (1).
3. Apparatus according to one of the claims 1 or 2, wherein each reflecting hood (31, 32, 33, 34) is capable of accumulating radiated heat energy from the cast product (1) and of transmitting said radiated heat energy to a specific zone of the cast product (1), wherein said specific zone is a surface of said cast product (1) whose cooling rate is higher than other surfaces of the cast product (1).
4. Apparatus according to one of the claims 1 to 3, wherein the cooling unit comprises a first cooling system (41) and a second cooling system (42), wherein the first cooling system (41) is designed for cooling the whole surface of the cast product (1) immediately downstream the mould (2) and is positioned before said heating system (3), and said second cooling system (42) is positioned downstream the first cooling system (41), before or together with said heating system (3) and is designed for cooling the hottest part of each face of said cast product (1).
5. Apparatus according to one of the claims 1 to 4, wherein the number of reflecting hoods (31, 32, 33, 34) equals the number of peripheral parts (11) of the cast product which are, during casting, farthest from the hottest part of said cast product in its cross section.
6. Apparatus according to one of the claims 1 to 5, wherein the reflecting hood (31, 32, 33, 34) is axially extended along the length of said elongated cast product (1).
7. Apparatus according to one of the claims 1 to 6, wherein said reflecting hood (31, 32, 33, 34) has a transverse section **characterized by** a parabolic shape or an L shape.
8. Apparatus according to one of the claims 1 to 7, comprising a system for measuring and analysing the surface temperature of the cast product (1), wherein said system for measuring and analysing comprises at least one temperature detector positioned immediately downstream the heating system (3) and is capable of commanding the moving system in function of a measured surface temperature value of the cast product (1).
9. Apparatus according to one of the claims 1 to 8, wherein the reflecting hood (31, 32, 33, 34) is made of an INCONEL alloy or another material having similar reflecting capacity.
10. Apparatus according to one of the claims 1 to 9, wherein the first cooling system (41) and the second cooling system (42) comprise each at least one spray (411, 421) for spraying the cast product surface with a cooling liquid.
11. A continuous casting machine capable of producing said elongated cast product (1), wherein said continuous casting machine comprises said apparatus according to one of the claims 1 to 10.
12. Method for controlling the temperature of an elongated cast product (1), downstream a mould (2) for casting said cast product, said method comprising the following steps:
 - a cooling of the surface of the cast product (1);
 - a controlled heating of a specific zone of the cast product (1), wherein said specific zone is a surface of said cast product whose cooling rate is higher than other surfaces of the cast product, wherein said heating is realized by a reflecting hood (31, 32, 33, 34) of a heating system (3), wherein each reflecting hood (31, 32, 33, 34) is able to accumulate radiated heat energy from the cast product and to transmit said radiated heat energy back to said specific zone of the cast product (1).
13. Method according to claim 12, comprising adjusting the covering of each peripheral part (11) of the cast product (1) which is, during casting, farthest from the hottest part of said cast product (1) in its cross section, by moving said reflecting hood (31, 32, 33, 34).

14. Method according to one of the claims 12 or 13, **characterized by** an adjustment of the position of each reflecting hood (31, 32, 33, 34) relative to the surface of the cast product (1) in function of heat transfer calculation and solidification/temperatures curves of the cast product (1). 5
15. Method according to one of the claims 11 to 13, **characterized by** a measurement of the surface temperature of the cast product (1) immediately downstream the heating system (3) and adjusting the position of each reflecting hood (31, 32, 33, 34) relative to the surface of the cast product in function of the measured temperature. 10

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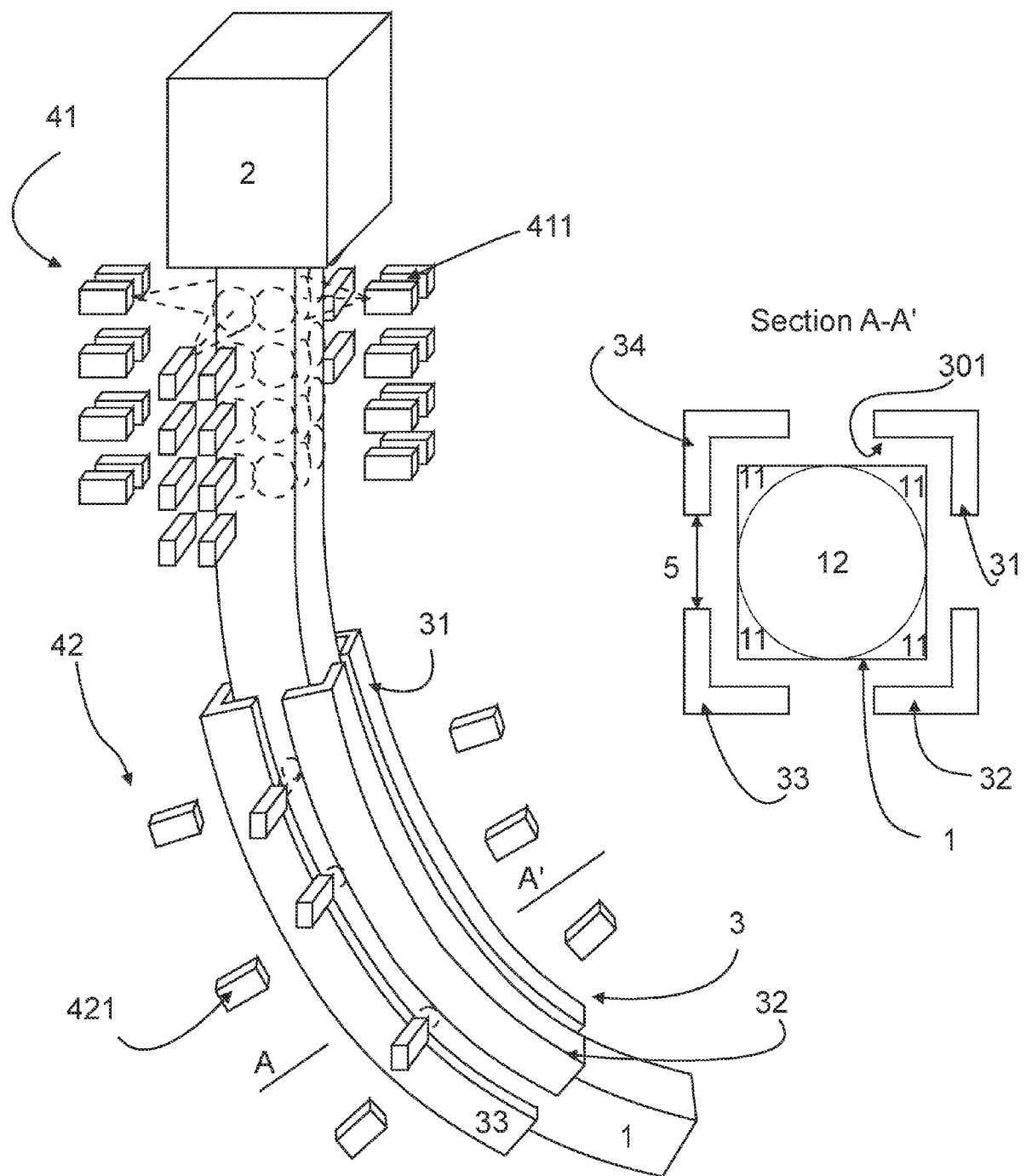


FIG 1

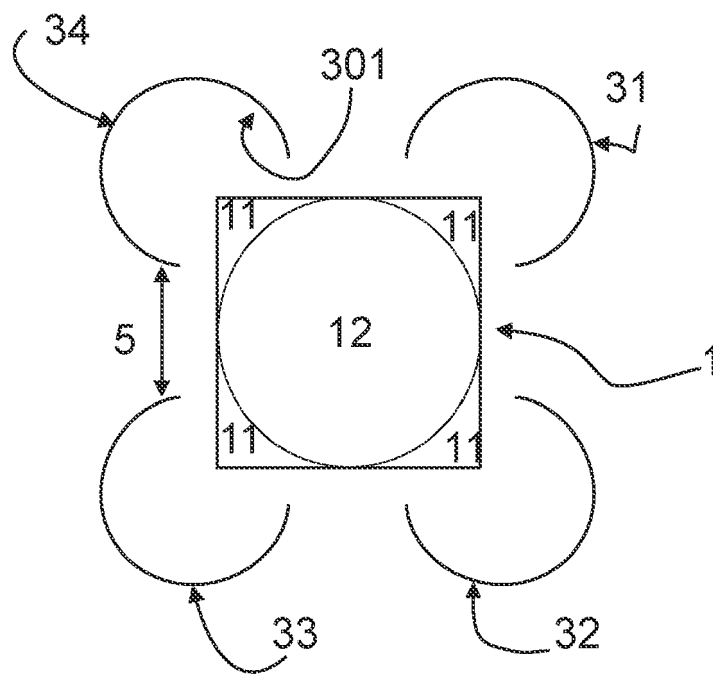


FIG 2



EUROPEAN SEARCH REPORT

Application Number
EP 11 17 5832

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Place of search		Date of completion of the search	Examiner
Munich		11 January 2012	Scheid, Michael
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 17 5832

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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