CLAIMS

1. A method of continuously producing steel intermediate products, comprising:

casting liquid steel into plural moulds to continuously produce plural bloom strands; and

feeding one or more of the bloom strands in line to respective rolling mills configured to be selectively engageable to hot roll the input continuously cast bloom strands to produce rolled billets,

wherein the rolling mills comprise two or more cantilever rolling mill stands in which bearing supports for the rollers of each stand support the rollers at only one end, and wherein the angle of the axes of the rollers of the first cantilever rolling mill stand for a given bloom is set at 45 degrees to the top surface of the bloom and wherein the angle of the axes of the subsequent rolling mill stands is set at 90 degrees to each other.

2. A method as claimed in claim 1, wherein the cast bloom strands fed in line to the rolling mills are still hot from the continuous casting, and wherein no additional reheating of the blooms is performed between the casting and hot rolling.

3. A method as claimed in claim 1 or 2, wherein the bloom strands have a cross sectional area above 230 square centimetres, and wherein the rolled billets have a cross sectional area below 230 square centimetres.

4. A method as claimed in claim 1, 2 or 3, further comprising:

feeding the bloom strands through respective straightening rollers;

operating each rolling mill at a speed based on a reference speed of the straightening rollers of the particular bloom strand fed to that rolling mill.

5. A method as claimed in any preceding claim, wherein a drive mechanism and a motor for each cantilever rolling mill stand is arranged outside the outermost strands produced by the continuous casting.

6. A method as claimed in any preceding claim, wherein each of the rolls for a given cantilever rolling mill stand is driven by an individual motor.

~~7. A method as claimed in any preceding claim, wherein each rolling mill comprises at least two, or preferably at least four, in line cantilever rolling mill stands arranged to roll increasingly small billet sizes.~~

~~8. A method as claimed in any preceding claim, wherein a housing for the bearing supports for each cantilever rolling mill stand is configured as a replaceable cassette.~~

~~9. A method as claimed in any preceding claim, wherein protective cooling or insulating jackets are provided around a housing for the bearing supports and/or a motor and/or a drive mechanism for each cantilever rolling mill stand.~~

~~10. A method as claimed in any preceding claim, wherein only one or both of the outermost strands of the plurality of continuously cast bloom strands is hot rolled into a billet, and wherein at least one innermost bloom strand is provided.~~

~~11. A method as claimed in any preceding claim, wherein the plural bloom strands are cast in a process of sequence continuous casting.~~

~~12. A method as claims in any preceding claim, wherein the rollers of the cantilever rolling mill stands are separated from each another to at least a distance wide enough for the cantilever rolling mill stands to clear the bloom and be moved out of the bloom casting line.~~

13. Apparatus for continuously producing steel intermediate products, comprising:

continuous casting apparatus arranged to, in use, continuously produce plural bloom strands; and

one or more in-line rolling mills each arranged to be selectively engageable to receive and hot roll, in use, one of the continuously cast bloom strands to produce rolled billets,

wherein the rolling mills comprise two or more cantilever rolling mill stands in which bearing supports for the rollers of each stand support the rollers at only one end, and wherein the angle of the axes of the rollers of the first cantilever rolling mill stand for a given bloom is set at 45 degrees to the top surface of the bloom and wherein the angle of the axes of the subsequent rolling mill stands is set at 90 degrees to each other.

~~14. Apparatus as claimed in claim 13,~~

wherein continuous casting apparatus comprises a tundish arranged to collect liquid steel and provide said liquid steel to plural moulds arranged side by side to continuously produce plural bloom strands,

wherein continuous casting apparatus comprises a ladle for having molten steel tapped therein from one or more furnaces, and having at its bottom a pipe opening arranged above the tundish for draining liquid steel into the tundish.

METHOD AND APPARATUS FOR PRODUCING STEEL INTERMEDIATE PRODUCTS

FIELD OF THE TECHNOLOGY

[0001] The present invention relates generally to methods and apparatuses for producing steel intermediate products. In particular, the present invention relates to methods and apparatuses for in-line rolling of billets from continuously cast blooms.

BACKGROUND

[0002] Rolling mills are installed for producing finished steel products, for example, for local markets in developing world countries and near markets for finished steel products, such as mild steel bar for use in civil construction. In countries where there is no significant production of semi-finished (cast) steel products, these rolling mills will typically rely on importing steel billets from other countries that have a larger steelmaking capacity, to finish for their local markets. This is prevalent in many developing world countries because even local production of steel intermediate products from recycled steel is not possible due to the scarcity of steel scrap generated locally, and the difficulties with providing a reliable and cost-effective supply of electrical power to operate an electric arc furnace. Therefore, imported billets are 're-rolled' to produce the finished steel products. These 're-rolling mills' typically take a starting billet size of up to 150mm by 150mm square (225 square centimetres) and are typically much smaller and have fewer production capabilities in terms of variety of input and output products, and production rate, compared to larger, dedicated rolling mills.

[0003] In the 1960s, production of billets was achieve by rolling cast ingots, each weighing 10 tons or more and such ingots were rolled into billets in a separate billet rolling mill. This antiquated method had no problem with rolling the ingots into the 150mm needed for the re-rolling mills described above. However, such a billet production method resulted in high end losses and has additional rolling costs, and so it was not particularly effective or efficient.

[0004] Since the 1970s, the "Continuous Casting" process has completely replaced the old ingots casting practice for producing intermediate steel products, and so now square

or round billets are typically directly casted from liquid steel using a "Continuous Casting Machine", rather than being rolled from cast ingots.

[0005] With today's very large capacity steel mills, producing, say, over 2 million tons of steel products annually, the continuously casted billets are of much larger cross section than is capable of being rolled by a 're-rolling' mill. For example, continuous casting machines producing "bloom" strands having a cross section of greater than 150mm by 150mm square, and up to 400mm by 400mm square (typically 240mm by 240mm square or in the case of a tube continuous casting machine, 250mm round) are now commonplace at the larger steel producing facilities. These blooms are larger than the typical maximum size billet of 150mm by 150mm square that can be rolled by the re-rolling mills described above. US 2002/189075 A1 provides certain disclosures in the field of producing steel products.

[0006] It is in this context that the present invention is devised.

SUMMARY OF THE INVENTION

~~**[0007]** Viewed from one aspect, the present invention provides a method of continuously producing steel intermediate products as claimed in claim 1.~~

~~[0008]~~[0007] In accordance with the present ~~invention~~disclosure, excess steel bloom production by a large capacity continuous steel casting machine can be directly converted to billets by an in-line hot rolling process, without the need for additional heating or reheating of the blooms before rolling. In this way, there is no need for a separate billet rolling mill to produce re-rollable billets from the continuously cast blooms, and as a result, this additional investment, double handling, extra manning, heating and rolling losses that would result from rolling reheated bloom lengths and which would make such billet production uneconomical, is avoided. In this way, large capacity multi-strand continuous casting machines are enabled to efficiently directly produce re-rollable billets by an in-line rolling process at the same time as producing larger blooms. By enabling, preferably selectable, production of readily-exportable billets directly from continuously cast bloom strands, large capacity steel intermediate production facilities can export surplus production for use in re-rolling mills in countries that rely on importing steel billets.

~~[0009]~~[0008] In embodiments, the cast bloom strands fed in-line to the rolling mills are still hot from the continuous casting, and wherein no additional reheating of the blooms is performed between the casting and hot rolling.

~~[0010]~~[0009] Preferably, the bloom strands have a cross sectional area above 230 square centimetres, and preferably the rolled billets have a cross sectional area below 230 square centimetres. Blooms typically are dimensioned above 150mm square (and up to 400mm square), the rolled billets typically are dimensioned below 150mm square.

~~[0011]~~[0010] In embodiments the method further comprises: feeding the bloom strands through respective straightening rollers; operating each rolling mill at a speed based on a reference speed of the straightening rollers of the particular bloom strand fed to that rolling mill. Using the speed of the individual straightening rollers for each continuously cast strand as a reference speed for the rolling speed of the rolling mill for that strand in this way enables the billets to be reliably hot rolled and the material flow balance to be maintained on a strand-by-strand basis.

~~[0012]~~[0011] The use of cantilevered rolling mill stands allows the rolling of each bloom strand to not interfere with the adjacent strand of the multi-strand bloom casting machine, and it allows the length of the rolling mill across all stands to be kept low and to be positioned as close as possible to the exit of the strands from the continuous casting machine, enabling the blooms to be rolled while still hot from the casting process, and before they have cooled. Conventional rolling mills, in which the rollers are "simply supported" with bearing supports at both ends of the rolling axis, would be too large to fit between the adjacent strands on exit from the continuous casting machine, and so would only be usable to roll the cast blooms if the strands were spaced further apart on exit from the continuous casting machine or moved further apart somehow by rollers. This is simply not practical.

~~[0013]~~[0012] In embodiments the drive mechanism and motor for each cantilever rolling mill stand is arranged outside the outermost strands produced by the continuous casting. In this way the bulky drive mechanism and motor components will not occupy space immediately above or below the bloom strands, such that the cast blooms are not interfered with.

~~[0014]~~[0013] In embodiments the drive mechanism and/or motor for the or each cantilever rolling mill stand is connected to the respective cantilever rolling mill stand by respective long shafts arranged so as to distance the drive mechanism and/or motor from the hot blooms. This enables the drive equipment and motors to be operated away from the high temperature environment immediately surrounding the cast blooms, improving their lifetime and reliability, and allowing conventional motors and mechanisms to be used that are not required to be designed to withstand extreme environments and temperatures.

~~[0015]~~[0014] In embodiments each of the rolls for a given cantilever rolling mill stand is driven by an individual motor.

~~[0016]~~[0015] In embodiments the angle of the axes of the subsequent rolling mill stands is set at 90 degrees to each other. Arranging the cantilevered rolling mill stands in this way allows the rollers to access the bloom strands from away to the sides of the bloom, reducing the extent to which the rollers and the rolling mill housing interfere with the space immediately surrounding the cast blooms. Further, by alternating the axes of the rollers in this way, the rolling mill housings and stands can be offset from each other and/or positioned alternately above and below the cast blooms allowing the rollers to be positioned close to each other axially along the strand, allowing the rolling mill to occupy a short length along the strand such that the cast strand can be rolled at a uniform temperature without significant cooling between the rolling mill stands. In embodiments each rolling mill comprises at least two, or preferably at least four, in-line cantilever rolling mill stands arranged to roll increasingly small billet sizes. In embodiments, each rolling mill stand will work on two faces of the bloom (for example, if the bloom is a 240mm by 240mm square cross section bloom) and the next rolling mill stand will work on the opposite two faces, rolling the cast blooms into smaller size billets.

~~[0017]~~[0016] In embodiments, it may not be desirable to further roll the bloom strands. Therefore the cantilever stands may be moved out of the line of the bloom casting without interrupting the casting process. The rolls of cantilever stands are separated from each another to at least a distance wide enough for the rolling mill stands to clear the bloom and be moved out of the bloom casting line.

~~[0018]~~[0017] In embodiments the housing for the bearing supports for each cantilever rolling mill stand is configured as a replaceable cassette, for example, that interfaces with the motor and drive mechanism. This will facilitate a quick changing of the rolls, for example when the rolls become worn, reducing downtime.

~~[0019]~~[0018] In embodiments, the rolling mill and each rolling mill stand is selectably operable or engageable with the cast blooms, allowing the bloom strands to be selectably hot rolled into billets optionally of varying sizes. This allows the output of the continuous casting machine to be selectably variable in size, allowing production to adapt readily to demand, for example, fluctuations in demand in domestic and/or export markets for cast blooms and (rolled) billets.

~~[0020]~~[0019] In embodiments protective cooling or insulating jackets are provided around the housing for the bearing supports and/or the motor and/or drive mechanism for each cantilever rolling mill stand.

~~[0021]~~[0020] In embodiments only one or both of the outermost strands of the plurality of continuously cast bloom strands is hot rolled into a billet. By rolling only the outermost strand(s), the degree to which the rolling mill interferes with the space around the cast bloom strands, and the degree to which the steel mill needs to be re-engineered to accommodate the rolling mill is minimized. In addition the requirements for the rolling mill stands are less stringent as the space requirements for rolling only the outermost strand(s) (due to the space availability to the sides of the strands) are less than those required for the innermost strands. In addition, excess production of continuously cast blooms, for example, for the domestic market, can, by operating on the outermost bloom strands, easily be hot rolled in-line into billets in the continuous casting process for direct export, for example, to developing world countries for re-rolling in a billet re-rolling mill.

~~[0022]~~[0021] ~~Viewed from another aspect, t~~The present invention provides apparatus as claimed in claim 1~~-13~~.

~~[0023] In embodiments the continuous casting apparatus comprises a tundish arranged to collect liquid steel and provide said liquid steel to plural moulds arranged side by side to continuously produce plural bloom strands.~~

~~[0024]~~[0022] In embodiments, the continuous casting apparatus is configured to operate in the methods ~~in accordance with the embodiments~~ described above.

BRIEF DESCRIPTION OF THE DRAWINGS

~~[0025]~~[0023] The invention, may best be understood by reference to the following description of certain exemplary embodiments together with the accompanying drawing in which:

~~[0026]~~[0024] FIG. 1 illustrates an apparatus and method of operation thereof for in-line rolling of billets from continuously cast blooms ~~in accordance with an embodiment of aspects of the present invention~~.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

~~[0027]~~[0025] The detailed description set forth below in connection with the appended drawings is intended as a description of presently preferred embodiments of the invention, and is not intended to represent the only forms in which the present invention may be practised. It is to be understood that the same or equivalent functions may be accomplished by different embodiments that are intended to be encompassed within the spirit and scope of the invention. Furthermore, terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that apparatuses and method steps that comprises a list of elements or steps does not include only those elements but may include other elements or steps not expressly listed or inherent. An element or step proceeded by "comprises ...a" does not, without more constraints, preclude the existence of additional identical elements or steps that comprises the element or step.

~~[0028]~~[0026] Referring now to Figure 1, which shows an apparatus 100 for in-line rolling of billets from continuously cast blooms in accordance with an embodiment of the present invention, a continuous casting machine 110 comprises a ladle 112, tundish 114, multiple permanent moulds 116 for forming strands 118 and straightening rollers 120 for straightening the strands.

~~[0029]~~[0027] Molten steel is tapped into the ladle 112 from one or more furnaces (not shown). The ladle 112 has at its bottom a pipe opening which is arranged above and drains liquid steel into a ~~holding bath or~~ tundish 114. The tundish 114 acts as a buffer reservoir and has shrouds or pipe openings into the permanent moulds 116. The liquid steel drains from the tundish 114 into the permanent moulds 116 which are shaped and liquid cooled to form a solidified exterior casing for the strands 118 that are formed by the hardened steel dropping due to gravity from the open bottom of the permanent moulds 116. In this case, five permanent moulds 116 are provided, but the number of permanent moulds could be greater or fewer than this, but is preferably at least two, and even more preferably greater than two or an even higher number in order to give a high production capacity. Each of the continuously cast strands 118 is then passed through sequences of pairs of individual straightening rollers that guide the strands to extend in a horizontal direction and straighten the strands as they move along between the rollers and cool and further solidify.

~~[0030]~~[0028] The continuous casting machine 110, and the permanent moulds 116 in particular are configured such that the strands 118 are formed as blooms having a cross sectional area above 230 square centimetres, in this case 240mm by 240mm square.

~~[0031]~~[0029] The continuous casting machine 110 has a high production capacity of, say 2 million tonnes a year, with a production speed of at least 4 metres per minute, and can operate continuously for a number of years of production between servicing. When this production capacity of continuously cast blooms exceeds demand, for example in the domestic market, which would lead to an increase in inventory of cast blooms, in accordance with the present invention, the apparatus 100 operates to hot roll one or more of the bloom strands 118 into billets 140 by operation of the in-line rolling mills 150, which can for example be exported to developing world markets for direct use in re-rolling mills. The rolled billets are formed to have a cross sectional area below 230 square centimetres, in this case 150mm by 150mm square.

~~[0032]~~[0030] The apparatus 100 is arranged such that the cast bloom strands 118 fed in-line to the rolling mills 140 in use are still hot from the continuous casting. No apparatus is provided arranged to perform additional reheating of the blooms between the casting and hot rolling.

~~[0033]~~[0031] The in-line rolling mills 150 comprise a plurality of cantilever rolling mill stands 152 in which the bearing supports for the rollers 154 of each stand support the rollers at only one end. The drive mechanism and motor 156 for each cantilever rolling mill stand 152 is arranged outside the outermost strands 118 produced by the continuous casting. In embodiments different to that shown in Figure 1, the drive mechanism and/or motor 156 for the cantilever rolling mill stands 152 can be connected to the respective cantilever rolling mill stand 152 by respective long shafts arranged so as to distance the drive mechanism and/or motor 156 from the hot blooms 118. To further reduce heating effects, in other embodiments protective cooling or insulating jackets can be provided around the housing 158 for the bearing supports and/or the motor and/or drive mechanism 156 for each cantilever rolling mill stand 152. Motors may be arranged to individually drive each of the rollers 154 for a given cantilever rolling mill stand 152.

~~[0034]~~[0032] For clarity's sake, in Figure 1, the second cantilevered rolling mill stand 152 of each rolling mill is drawn with the drive mechanism and motor 156 and the housing 158 below the strands 118 at floor level. However, in other embodiments, to avoid mill scale build up on the machinery, the rolling mills 150 can be arranged such that the drive mechanism and motor 156 and the housing 158 of the cantilevered rolling mill stands 152 are never positioned underneath the strands 118 by, for example, positioning certain components above floor level.

~~[0035]~~[0033] The housing 158 for the bearing supports for each cantilever rolling mill stand 152 is configured as a replaceable cassette, for facilitating a quick changing of the rolls, e.g. when worn, reducing down time.

~~[0036]~~[0034] Each rolling mill 150 (for each strand) comprises two in-line cantilever rolling mill stands 152. In other embodiments, more than two or preferably at least four, cantilever rolling mill stands are provided, arranged to roll increasingly small billet sizes. The angle of the axes of the rollers of the first cantilever rolling mill stand for a given bloom is set at 45 degrees to the top surface of the bloom. The angle of the axes of the subsequent rolling mill stands is set at 90 degrees to each other.

~~[0037]~~[0035] Each rolling mill 150 is configured to operate at a speed based on a reference speed of the straightening rollers of the particular bloom strand 118 fed to that rolling mill. This ensures a balance to the flow of material through the rolling mills 150.

~~[0038]~~[0036] As shown in Figure 1, both of the outermost strands of the plurality of continuously cast bloom strands 118 is hot rolled into a billet. The in-line rolling mills 150 are in position and operate continuously such that rolled billets are always produced. The rolling mills 150 can be selectively engaged such that billet production can be responsive to variation in demand for cast bloomed and rolled billets for re-rolling. Therefore the cantilever stands may be moved out of the line of the bloom casting without interrupting the casting process. The rollers 154 of the cantilever stands are separated from each another to at least a distance wide enough for the rolling mill stands 150 to clear the bloom and be moved out of the bloom casting line.

~~[0039]~~[0037] The invention is applicable not just to square blooms, but also to round blooms for which appropriate permanent moulds and straightening rollers need to be provided. The roll pass section then needs to be adjusted accordingly to produce billets of the desired square (or other) cross section.

~~[0040]~~[0038] In a further embodiment of the present invention, the strands are cast in a process of sequence continuous casting. This process enables different temperatures of liquid steel to be continuous-continuously casted, i.e. without interruption. This process increases productivity by eliminating the need to prepare for starting a new individual casting process each time. Through the use of adjustable cantilevered rolling mill stands the present invention allows for the blooms width to be adjusted and liquid steel of different temperatures to be cast continuously. Steel of different temperatures may be utilised by replacing the tundish comprising the steel of a different temperature.

~~[0041]~~[0039] The description of the preferred embodiments of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or to limit the invention to the forms disclosed. It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. It is understood, therefore, that this invention is not limited to the particular embodiment disclosed, but

covers modifications within the scope of the present invention as defined by the appended claims.