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(54) PROCESS FOR MULTI-MODE MANUFACTURING OF METAL STRIPS AND PLATES

(57) A process for the endless or batch production of strips and plates of hot-rolled steel, with thickness from 0,6 mm to 50 mm, comprises the continuous casting (1) with liquid core reduction of a thin slab (S) having a minimum thickness of 80 mm, followed by a heating in an induction heater (2), a finishing rolling (4), a controlled cooling (6) and a final shearing (5; 8), and further includes prior to said heating in an induction heater (2) an initial rolling (10) with a thickness reduction of the slab (S) of only about 10% and in any case not more than 20%, starting from a thickness reduction of about 8 mm.

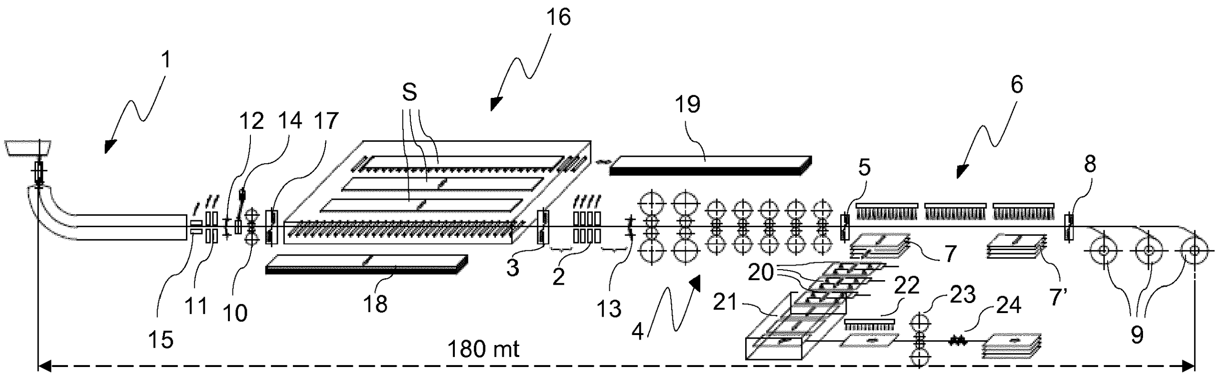

Fig.1

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Description

[0001] The present invention concerns a process for the continuous or batch production of hot rolled strips and plates, in a wide size range with high plant productivity and cost effectiveness and high product quality.

[0002] It is known that in the steel industry, considering both rising costs of the raw materials and energy used and also the greater competitiveness required by the global market, as well as the increasingly restrictive regulations in terms of pollution, there is a particularly strong need for a manufacturing method for high-quality hot-rolled steel strips and plates which requires lower investment and production costs and greater production flexibility. Consequently, greater competitiveness can thus be given to the end product processing industry with lower energy consumption, in this way also reducing the negative impact on the environment to a minimum.

[0003] The state of the art is substantially the one described by the same inventor in his prior patents, in particular EP 1558408 and EP 1868748 which are referred to for further details. In EP 1558408 the so-called "cast-rolling" technology is used which unites the continuous casting of a thin slab with liquid core reduction (LCR) to a first roughing rolling step through a high-reduction mill (HRM) or roughing mill that achieves an intermediate product which, after a heating phase in an induction heater and subsequent descaling, is further processed in a second phase of finishing rolling.

[0004] Also foreseen in the afore-mentioned patent EP 1558408 is the possibility of extracting rough-rolled plates after the first roughing rolling step as an emergency system in case of problems in the portion of the plant downstream of the roughing mill in order to prevent the interruption of the continuous casting process and consequently the production on the line. Given the absence of a controlled cooling system necessary for the production of quality plates, these plates cannot be sold and must necessarily be reduced to scrap to be re-introduced into the production cycle.

[0005] Both in EP 1558408 and in other plants of prior art, between the exit of the roughing mill and the entry to the finishing mill the intermediate product shows a temperature decrease of about 230°C which must be compensated by means of the induction heater so that at the exit of the finishing mill the product still has a temperature of more than about 820-850°C which corresponds to the lower end of the austenitic temperature range.

[0006] EP 1868748 teaches some improvements from the point of view of plant compactness and energy saving, providing that the continuous casting is directly connected with a rolling step in a single manufacturing step without solution of continuity. In practice there are no longer two separate rolling steps, roughing and finishing, but a single rolling step and the distance between the outlet of the continuous casting and the first stand of the rolling mill will not be greater than 50 m in order to limit the temperature losses of the slab. EP 1868748 also provides the production of plates only with "endless" mode and using the same cooling system used for coils, a solution which has proved to be not optimal for the production of plates since the "endless" mode works better for coils and the optimal cooling parameters for plates are significantly different from those for coils.

[0007] Other prior art casting and rolling plants are described in WO 2007/045988 and DE 102011004245. In the first case, the cast slab has a maximum thickness of 50 mm prior to the liquid core reduction that takes it to 40 mm and it undergoes a maximum thickness reduction of 3 mm performed by the pinch rolls located just downstream from the casting machine. In the second case, a roughing mill is arranged just downstream from the casting machine to perform a slab thickness reduction up to 70%, but in case of problems along the subsequent rolling line said thickness reduction can temporarily be reduced down to zero.

[0008] The results obtained so far with the teachings of the above-mentioned patents, though optimal as far as product quality is concerned and in particular for steel strips, have shown that there are still margins of improvement as to technology, plant, productivity and production flexibility. The following areas have been identified as needing improvements:

1. Introducing the possibility for production in "batch" mode or "combined" mode with an interruption of the cast slab between the caster and the rolling mill, in other words the slab that enters the rolling mill is separate and with a different speed from the one present in the continuous casting machine. This possibility provides important plant and production flexibility since:

   - In the manufacture of coils with a thickness greater than 3 mm, using a "batch" mode instead of an "endless" mode avoids having pieces of strip of significant weight that are outside the tolerances between two contiguous coils which, due to production scheduling requirements, must necessarily have different thicknesses.
   - In the manufacture of coils with a thickness greater than 1,5-2,0 mm, in which the mass flow of the caster may be lower than that of the rolling mill, a "batch" mode allows a reduction in energy consumption, in particular in the induction heater, thanks to the higher rolling speed and the consequent reduction in the heat losses.
   - In the manufacture of quality plates, where the mass flow of the caster must be lower than that of the rolling mill due to the necessity of maintaining a reduced casting speed required by the type of steel being cast.
   - In the manufacture of coils with a significant thickness difference between two contiguous coils which requires a change of setting in the gaps of the rolling stands when there is no ma-

terial passing therethrough, a "combined" mode allows to produce a first coil mostly in "endless" mode but the last portion thereof is produced in "batch" mode by cutting the slab so that it can be accelerated and rolled faster in order to create the time interval required for the re-setting of the empty rolling mill for the production of the second coil of different thickness.

2. Improving the quality of the slab surface prior to the rolling step;
3. Introducing a "mechanical filter" between the continuous caster and the pendulum shear used in the plants that adopt the "batch" technology, so as to avoid the problems encountered when the cutting of the slab by the pendulum shear may create perturbations in the casting machine as far back as the meniscus of the mould.
4. Increasing plant profitability by producing slabs, in the case of unavailability of the rolling mill due to cobbles that may be subsequently heated and rolled, instead of plates that might be scrapped as in the plants which follow the teachings of the prior art.
5. Increasing plant profitability by introducing the possibility of rolling slabs:

- produced at the same works and loaded into the production cycle in the case of unavailability of the melting plants at said works, in particular the slabs mentioned in point 4 above, and/or
- bought on the market at advantageous prices in certain scenarios.

6. Increasing the quality of the plates produced, by introducing a dedicated cooling system possibly followed by a dedicated plates treatment line.
7. Increasing the production to 4.000.000 ton/year by increasing the casting speed to 9 m/min and consequently the relative mass flow to 8 ton/min.
8. Further improving strip width tolerances.
9. Reducing the strip width without intervening on the positioning of the narrow faces in the continuous casting mould, which leads to an increase in productivity since it allows the mould width and consequently the mass flow to remain unchanged.
10. Further increasing the edge quality of both strips and plates.

[0009] The aim of the present invention is therefore to provide a solution for the production of continuously hot rolled strips or plates with strip thickness from 0,6 mm to 12 mm and plate thickness from 12 mm to 50 mm or in any case half of whatever may be the slab thickness at the exit of the continuous caster with liquid core reduction, said thickness having a minimum value of 80 mm, with maximum width at least 2100 mm or whatever may be the maximum mould width foreseen, with plate and strip quality the same or better, lower energy consumption, lower impact on the environment, higher productivity and flexibility compared with the afore-mentioned prior art.

[0010] This result is obtained with the use of both "endless" production technology without interruption of the cast slab and "batch" or "combined" production technology with interruption of the cast slab between the caster and the rolling mill, in order to achieve production flexibility not to be found with plants built following the teachings of the prior art.

[0011] The advantageous measures adopted in the present invention to improve the process in question include:

a) Introducing between the continuous caster and the induction heater a minimum-reduction rolling stand (so-called "kiss pass" stand) which allows to achieve:

- optimisation of the crystalline structure of the slab, by recrystallizing the coarse grains which make up the slab surface at the exit of the continuous caster, in order to obtain smaller grains which tend to detach from each other less easily in the subsequent rolling step,
- creation of a "mechanical filter" between the caster and the subsequent shear cutter, in order to avoid the above-mentioned problems encountered in the prior art plants using "batch" technology.

b) Introducing a narrow face vertical rolling stand (edger), preferably positioned upstream of the first rolling stand (i.e. the "kiss pass" stand), in order to:

- recrystallize the edges of the slab which are the coldest parts and therefore those most sensitive to the formation of cracks,
- shape the slab edges for minimizing the tension stresses in the subsequent rolling step,
- improve the increasingly strict width tolerances required by end customers,
- reduce the width of the slab by up to 50 mm on each side without reducing the plant productivity.

c) Introducing between the "kiss pass" stand and the induction heater an interconnecting roller hearth furnace or walking beam furnace that makes possible to:

- evacuate slabs, in the case of unavailability of the rolling mill, that may subsequently be taken up again for production instead of becoming plates that might be scrapped.,
- select between three production operating modes, namely "endless" (optimal for the production of thin strips) or "combined" and "batch" (optimal for the production of thicker strips and

for the production of plates),

- start the production cycle from slabs introduced into the furnace at ambient temperature,
- store and load the hot slabs produced and present in the furnace used as a buffer because of a cobble in the rolling mill, once the rolling mill is again available.

d) Introducing a specific cooling system for the plates downstream of the rolling mill, possibly followed by a dedicated plates treatment line.

[0012] Further advantages and features of the process according to the present invention will be evident to those skilled in the art from the following detailed and non-limiting description of an embodiment thereof with reference to the only drawing, attached as Fig.1, that shows a schematic view of a plant performing the process in its most complete embodiment.

[0013] With reference to Fig.1, there is seen that a plant performing the process according to the present invention conventionally includes a continuous caster 1 followed at a certain distance by an induction heater 2, with a pendulum shear 3 therebetween, and then a rolling mill 4 followed by a rotary shear 5 and a run out table with a cooling device 6 and a pusher or pusher/piler 7 for plates and finally a high-speed shear 8 before the down coilers 9.

[0014] More specifically, caster 1 includes a mould followed by a curved liquid core reduction section to produce a slab with a minimum thickness of 80 mm, e.g. 100 mm x 2100 mm, at a casting speed up to 9 m/min. Said slab is then heated by the induction heater 2, comprising four coils in the illustrated example, prior to entering the finishing rolling mill 4, comprising up to seven stands as in the illustrated example, in which the slab undergoes a progressive thickness reduction with decreasing reduction rates, e.g. 58%; 52%; 47%; 43%; 40%; 35%; 30% and work rolls of larger diameter in the initial stands (e.g. the first two in the illustrated example).

[0015] The finishing rolling mill 4 may also include, at any position after the first two stands, cooling and/or heating devices (e.g. gas or induction heaters) located between the rolling stands so as to be able to better control the rolling conditions by adapting the temperature of the material being rolled to its specific characteristics and needs.

[0016] The resulting strip is then cooled by the cooling device 6 and finally coiled by the down coilers 9 and cut by the high speed shear 8 when the coil has reached the intended weight. Alternatively, if the slab is reduced to plate thickness only it is then cut into plates by the rotary shear 5 and said plates are moved out of the line by the pusher or pusher/piler 7, possibly after having been cooled in the first section of the cooling device 6.

[0017] A first novel aspect of the present invention resides in the presence of a so-called "kiss pass" stand 10 between the continuous caster 1 and the pendulum shear 3, said stand 10 performing a thickness reduction of only about 10%, and in any case not more than 20%, therefore starting from a minimum reduction of about 8 mm, that has a metallurgical rather than a mechanical purpose. In fact, as mentioned above, this minimum reduction is aimed at the optimisation of the crystalline structure of the slab surface by recrystallizing the coarse grains coming out of the caster in order to obtain smaller grains which are less prone to detach from each other in the actual rolling step carried out in the rolling mill 4. The plant also preferably includes, between caster 1 and stand 10, an additional induction heater 11, comprising two coils in the illustrated example, and a descaler 12 so as to: a) avoid the ductility draft temperature ranges, b) keep segregating elements in solution, and c) improve the result of the "kiss pass" reduction (similarly, a further descaler 13 preferably precedes the rolling mill 4).

[0018] Furthermore, the presence in the cast alloy of low-melting elements (e.g. copper and tin as in the steel produced from scrap in an EAF) that tend to gather at the edges of the grains makes said edges even weaker, and the problem obviously increases with the concentration of said low-melting elements. The recomposition and refining of these grains achieved through this "light" reduction pass provides the double advantage of being able to: a) apply a higher reduction rate in the subsequent first actual reduction step without breaking the material at the surface, and b) obtaining strips/plates of the same high quality even using cheaper and lower-quality scrap, i.e. scrap containing higher concentrations of impurities such as copper and tin.

[0019] It should be noted that the "kiss pass" stand 10 preferably includes working cylinders of smaller diameter with respect to the first stand in the rolling mill 4, since it must apply a minimum reduction while cooling the slab as little as possible, whereby a smaller arc of contact is sufficient and preferable with the advantage that tension stresses at the surface of the rolled stock are minimized.

[0020] Another advantage obtained by arranging the "kiss pass" stand 10 between the continuous caster 1 and the pendulum shear 3, as mentioned above, is the creation of a "mechanical filter" between said two components so as to avoid any disturbance in caster 1 when the slab is cut by shear 3 in case of emergency if there is a cobble in the portion of plant downstream from shear 3.

[0021] A second novel aspect of the present invention resides in the presence of an edger 14, i.e. a narrow face vertical rolling stand, that is preferably positioned immediately upstream from the "kiss pass" stand 10 and preferably preceded by an induction edge heater 15, i.e. a heater with C-shaped coils that heat only the edges of the slab. However, edger 14 could also be arranged immediately upstream from the rolling mill 4 together with its corresponding induction edge heater 15 that could be arranged adjacent to the induction heater 2 on any side thereof.

[0022] As previously mentioned, the addition of edger

14 allows to recrystallize the slab edges, which are the coldest parts and therefore those most sensitive to the formation of cracks, to shape them for minimizing the tension stresses in the subsequent rolling step and to improve the width tolerances. Moreover, edger 14 can reduce the slab width on each side by up to 50 mm whereby a narrower strip/plate can be obtained without any intervention on the mould and thus without reducing the plant productivity.

[0023] A third novel aspect of the present invention resides in the presence, between the "kiss pass" stand 10 and the induction heater 2, of an interconnecting furnace 16 suitable to allow the introduction/removal and the controlled advancement of slabs S. A typical example is a gas-heated roller hearth furnace or walking beam furnace, usually about 30 m long, but other equivalent types of furnace can obviously be used.

[0024] Said furnace 16 is immediately preceded by an additional pendulum shear 17 so that, as previously mentioned, the present plant not only makes possible to evacuate through a piler 18 re-usable slabs in the case of unavailability of the rolling mill 4, but also to select between the "endless" and "batch/combined" operating modes, as well as to load into the interconnecting furnace 16 (through a loading station 19) slabs at ambient temperature that have been bought on the market. The furnace 16 also acts as a buffer to hold and then subsequently load to the rolling line the hot slabs produced and stored in the furnace because of a cobble in the rolling mill 4, once the latter is available again.

[0025] Note that the "kiss pass" stand 10 is located between the continuous caster 1 and the additional pendulum shear 17 therefore it acts as a "mechanical filter", as mentioned above, also between said two components so as to avoid any disturbance in caster 1 when the slab is cut by shear 17 to select the "batch/combined" mode.

[0026] Considering that a given percentage of thickness reduction of the slab implies a corresponding percentage of length increase since the slab width remains unchanged, it is noted that the "kiss pass" stand 10 can be used as a first rolling pass upstream from furnace 16 exactly because it performs a thickness reduction of about 10%, and not more than 20% in any case. Such a reduction is much smaller than the thickness reduction in a roughing mill or in the first stand of a finishing rolling mill according to the prior art, which is in the order of 50-70%, that would result in an unacceptable length of furnace 16. In fact, the furnace must be sized to hold a slab of a weight corresponding to the weight of a finished coil of strip or a stack of plates to be produced in a batch production cycle, whereby an excessively thinned slab would have an unacceptable length to obtain the required weight.

[0027] This is also the rationale behind the above-mentioned 20% reduction limit, otherwise it is clear that a greater reduction in the "kiss pass" stand 10 would be helpful in achieving more easily the desired final thickness in the rolling mill 4, that could possibly have fewer stands. However there is also a "metallurgical limit" that depends on the alloy composition, whereby the "kiss pass" stand 10 can only achieve a maximum thickness reduction that is suitable to obtain the required recrystallization of the grains without causing a breaking of the slab surface.

[0028] A fourth novel aspect of the present invention resides in the fact that the cooling device 6 may include a first cooling section capable of performing an ultra-fast cooling of the plates that corresponds to a quenching thereof. A subsequent tempering at a later working step will provide plates having a higher quality with respect to those produced with prior art plants whose cooling sections are only optimized for strips.

[0029] Alternatively, a plate-specific cooling device 20 may be arranged offline such that the plates removed by the pusher or pusher/piler 7 undergo a multi-stage high-pressure cooling, i.e. each intense cooling stage is followed by an interval in which the temperature of the plate has the time to become substantially homogeneous prior to the successive cooling. In this way it is possible to obtain the desired cooling pattern for each steel grade, and the cooling device 20 may be followed by a tempering furnace 21, a further controlled cooling 22, a skin pass stand 23 and a roller leveller 24 for a complete treatment of the plates (either cooled in the specific cooling device 20 or in the above-mentioned ultra-fast cooling section of the cooling device 6).

[0030] Another possibility is to provide a cooling device 6 that can be easily adjusted to a plate-specific setting, and in such a case it is obvious that the pusher/piler 7 or an additional pusher/piler 7' would be located between the cooling device 6 and coilers 9. In this way the cooling device 6 can be properly used for the cooling of both high-quality strips and high-quality plates.

[0031] The above-described process according to the present invention is therefore suitable for producing both high-quality strips and high-quality plates, either in "endless" mode with no solution of continuity of the slab between caster 1 and rolling mill 4 (i.e. the entry speed of the rolling mill 4 is linked to the casting speed through the speed increase in the kiss pass stand), or in "batch/combined" mode with the slab that enters the rolling mill 4 which is disconnected from the slab in caster 1.

[0032] Furthermore, such a process can use as starting material also slabs coming from the interconnecting furnace 16, either loaded at ambient temperature through the loading station 19 or held at high temperature in furnace 16 itself when used as a buffer.

Claims

1. Process for the continuous or batch production of strips and plates of hot-rolled steel with thickness from 0,6 mm to 50 mm or half of the maximum thickness of a cast slab, comprising the continuous casting (1) with liquid core reduction of a thin slab (S)

having a minimum thickness of 80 mm, followed by a heating in an induction heater (2), a finishing rolling (4), a controlled cooling (6) and a final shearing (5; 8), **characterized in that** it further includes prior to said heating in an induction heater (2) an initial rolling (10) with a thickness reduction of the slab (S) of only about 10% and in any case not more than 20%, starting from a thickness reduction of about 8 mm.

2. Process according to claim 1, **characterized in that** the initial rolling (10) is preceded by a heating in an additional induction heater (11) and a descaling (12).

3. Process according to claim 1 or 2, **characterized in that** it further includes a vertical rolling (14) of the narrow sides of the slab with a possible width reduction of up to 50 mm on each side, said vertical rolling (14) taking place immediately before the initial rolling (10) or the finishing rolling (4).

4. Process according to the preceding claim, **characterized in that** the vertical rolling (14) is preceded by a heating of the slab edges in an induction edge heater (15).

5. Process according to any of claims 1 to 4, **characterized in that** in the case of production of plates the controlled cooling (6) includes an ultra-fast cooling of the plates that corresponds to a quenching thereof.

6. Process according to any of claims 1 to 4, **characterized in that** in the case of production of plates it further includes the removal (7) of the plates after the finishing rolling (4) and a multi-stage high-pressure cooling of the plates in a plate-specific offline cooling device (20).

7. Process according to claim 5 or 6, **characterized in that** it further includes in sequence a tempering (21), a controlled cooling (22), a skin passing (23) and a levelling (24) of the plates after their ultra-fast or multi-stage high-pressure cooling.

8. Process according to any of claims 1 to 4, **characterized in that** in the case of production of plates the controlled cooling (6) is adjusted to a plate-specific setting and the removal (7') of the plates occurs after the controlled cooling (6).

9. Process according to any of claims 1 to 8, **characterized in that** it further includes a step of using as starting material slabs (S) coming from the interconnecting furnace (16), either loaded at ambient temperature through the loading station (19) or held at high temperature in the furnace (16) itself when used as a buffer.

10. Process according to any of claims 1 to 9, **characterized in that** it further includes a step of cutting slabs (S) with the fourth shear (17) and removing them from the interconnecting furnace (16) by means of the piler (18) in case of troubles in the portion of the plant downstream from said interconnecting furnace (16).

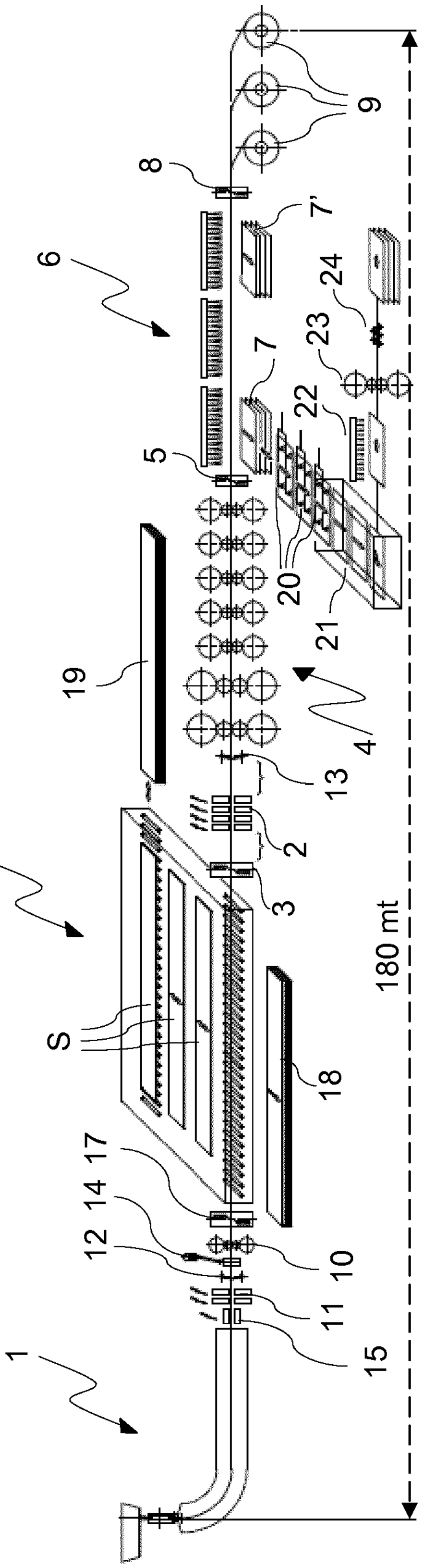

Fig.1

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EUROPEAN SEARCH REPORT

Application Number
EP 19 20 8335

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2007/045988 A2 (DANIELI OFF MECC [IT]; BENEDETTI GIANPIETRO [IT]; POLONI ALFREDO [IT];) 26 April 2007 (2007-04-26) * page 17, line 23 - page 21, line 15; figures 1,2 * -----	1-10	INV. B21B1/46
A	DE 10 2011 004245 A1 (SMS SIEMAG AG [DE]) 12 April 2012 (2012-04-12) * paragraph [0047] - paragraph [0059]; figure 1 * -----	1-10	

TECHNICAL FIELDS SEARCHED (IPC)

B21B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	27 February 2020	Frisch, Ulrich

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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27-02-2020

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REFERENCES CITED IN THE DESCRIPTION

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