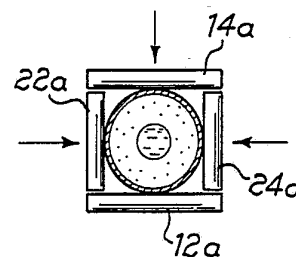
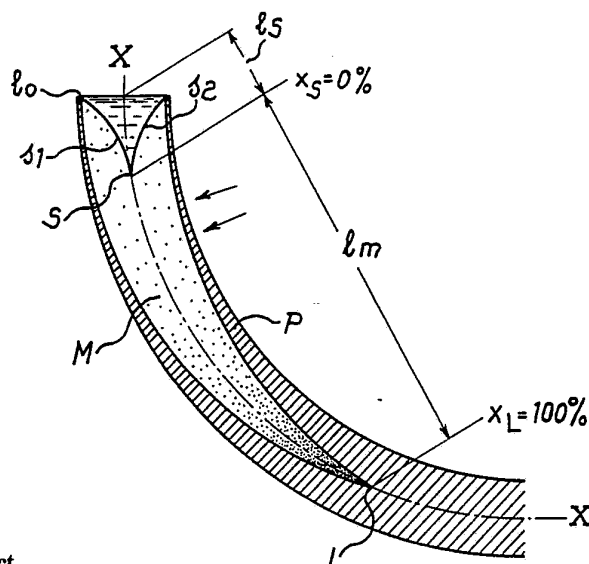




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(54) Title: A PROCESS AND AN APPARATUS FOR THE MANUFACTURE OF BILLETS AND BLOOMS FROM A CONTINUOUSLY CAST STEEL SHOWING HIGH OR EXCELLENT QUALITY



(57) Abstract

A process for the manufacture of billets and blooms from continuously cast steel, allowing such long products to be directly conveyed to a finishing rolling mill in a plant supplying high quality steel and/or excellent quality steel. Said process is comprising a liquid core distortion stage, concerning the casting cross section and causing the reduction of the same cross section, the perimeter remaining unchanged (equal). Said distortion occurs in the zone comprised between the point (S), last point on the casting axis (X-X) where superheated liquid is still present, and the point (L) where the casting is completely solidified (end of the metallurgical length). Preferably, said distortion is carried out between the points respectively corresponding to 10 % and 80 % of the concentration of solid grains in the fluid mass. An apparatus is described too, essentially comprising means for bringing at least one of the sectors forming the roller train (along the casting route) near the opposite one, in at least one plane containing the casting axis (X-X), in correspondence of said distortion zone.

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A PROCESS AND AN APPARATUS FOR THE MANUFACTURE OF BILLETS AND BLOOMS FROM
A CONTINUOUSLY CAST STEEL SHOWING HIGH OR EXCELLENT QUALITY

The present invention relates to a process for the direct manufacture of billets and blooms from a continuously cast steel showing high or excellent quality, as well as an apparatus for the realization of such process.

It is known that the continuous casting is ever more utilized for the manufacture of steel, because of the clear and well known advantages therein involved, with respect to other kinds of casting. It is clear however that the thus obtained product, as it appears at the extracting machine at the end of the curvilinear casting route, shows the features of a typical casting piece, with all the qualitative drawbacks typical of these semifinished products. It is in fact possible to see, by a metallographic analysis, that the grain size and the structure isotropy are unsatisfactory and that the carbon percentage is not homogeneous but prevalently concentrated in the central zone of the product, with a (consequent) kish (segregation), which makes the product, coming from the continuous casting, not directly exploitable for the rolling, when it is desirable to obtain end products consisting of high and excellent quality steel.

In the case of a high quality steel, the continuous casting can be exploited for obtaining blooms, which, a-

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fter transit through an oven, are conveyed to a size-breaking rolling mill, in order to be converted into billets, which in their turn, optionally heated in a further oven, are eventually conveyed to a finishing rolling mill. In the case of an excellent quality steel, the casting is even occurring in the form of an ingot, and not in a continuous way, and in each ingot the cooling is adjusted by means of a predetermined cycle; therefore, the ingots, or the big size blooms, are conveyed to the size-breaking and subsequently to the pre-rolling (cogging) and to the finishing rolling, wherein there are usually provided, between two subsequent operations, intermediate heatings in an oven, thus performing an extremely long and expensive operative cycle.

It is thus a purpose of the instant invention to supply a process allowing the direct manufacture, by means of a continuous casting, of billets or blooms showing such features as to be easily transferred, in a subsequent time and without any further operation, to the finishing rolling. Another object of the instant invention is residing in an apparatus for the realization of said process.

An advantage coming from the process according to the invention, described hereinbelow, is residing in that the consequent inner grain of the casting product is showing those features of fineness, homogeneity and isotropy, as well as of absolute absence of kish (segregation), which are usually observed in a product ready for the finishing rolling, thus omitting the steps concerning size-breaking and pre-rolling, including the

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respective intermediate heatings, and thus reaching a considerable power saving.

The process according to the instant invention is characterized by a liquid core distortion of the casting product, obtained by means of a continuous casting, which causes a reduction of the product cross-section, the perimeter of the same cross-section being unchanged, in the route between the lowermost geometrical point on the casting axis, where it is still possible to find superheated liquid, and the end point of the metallurgical length, where the product is completely solidified.

According to a preferred embodiment of the instant invention, said distortion is made to occur in a zone where the concentration of the solid grains is from 10 to 80%.

The distortion hereinabove, from a practical point of view, can involve the conversion of the shape from round to square (billet) or to rectangular (bloom), or from billet to bloom or also, starting from this latter, to a more flattened cross-section.

The apparatus for carrying out the process according to the invention is essentially comprising at least one of the sectors of the roller train along the curvilinear route, which is given the possibility of movement with respect to the opposite sector, and means fit for bringing said mobile sector near the opposite one on at least one plane containing the casting axis.

The purposes, the advantages and the features of the process and of the apparatus according to the instant invention will be clearer from the following detailed

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description and drawings, which are supplied for illustrating purposes but do not limit in any way the scope of the same invention.

As to the drawings:

5 FIGURE 1 is showing an extremely schematic view of the sole casting product along the curvilinear route, in order to point out the basic parameters of the process according to the invention;

FIGURE 2 is showing an equally schematic view of a continuous casting apparatus, modified as to realize the
10 process according to the invention; and

FIGURE 3 is showing a section view along line III-III of Fig. 2, in the case of the distortion of a rod.

Referring now to Fig. 1, there is represented, in an
15 extremely schematic way and in a section containing the casting axis X-X, a product made from steel during a continuous casting. By l_0 there is indicated the free surface of the liquid in the ingot mold (ladle) and by S the lowermost geometrical point, on the casting axis,
20 where it is still possible to find superheated liquid.

In other words, below S the temperature reaches the "liquidus" value, typical of each peculiar steel, whereas above the two lines s_1 and s_2 the temperature value is higher and the liquid, in such zone, is super-
25 heated and void of solid grains.

The position of point S can be determined, for each casting mill, depending on the temperature value of the still contained in the ladle above the "liquidus" value, according to the kind of the steel, and can be expressed by means of time terms (t), corresponding to a
30 certain speed. From the determination of the time t it

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is possible to extrapolate the position of S depending on the different possible casting velocities.

It is usually supposed that point S be lying below the ladle, and precisely in the first leg of the roller train, commonly defined "segment zero" (extractable section). L is representing the point where the casting product is completely solidified and the distance l_m , observed between such point and point S, is commonly defined "metallurgical length".

10 It is believed that the liquid lying below the two lines s_1 and s_2 and comprised between such lines and the inner walls of the already solidified portion P ("skin") be already containing solid grains with a concentration increasing towards the lower zone, until the
15 complete solidification in L. In this viscous or semi-solid mass (M) are in fact in equilibrium either the true actual liquid or the solid suspended grains. On the X-X axis, the concentration of the solid grains in the mass (M) is equal to zero in S and to 100% in L,
20 linearly increasing along with the metallurgical length.

The progression speed of the solid portion P is clearly equal in every point, whereas the speed of the mass (M) has to fulfill a different condition, namely to feed
25 the solidification process as to avoid the formation of empty zones before point L, which would involve the presence of cracks in the end product. It has to be furtherly remarked that the metallurgical length l_m has to be such as to allow point L to be upstream of the
30 extraction device 20, lying at the end of the curvilinear casting route (see Fig. 2).

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It was now surprisingly found that by compressing according to the invention the walls P of the "liquid core" casting product, namely before point L, thus reducing the volume of the same product by distorting its cross-section, there is obtained a bloom or a billet showing all the desired features hereinabove fit for obtaining a steel product having a high or excellent quality.

The mechanism allowing such a transformation is not completely clear, but it is believed that by bringing the solid walls P near each other, there occurs, inside the fluid mass M, which contains already solidified grains and which can be defined semisolid or "viscous", a speed gradient or acceleration, causing the breaking of the dendritic branchings which tend to form inside the same mass. The thus crushed grains get reduced in their size and are oriented in a way as random (casual) as possible, thus acquiring particular isotropy and homogeneity features, while avoiding segregations, namely increasing concentrations of carbon (kish) towards the inner portion of the product.

An essential condition, in order to make such results to occur, is however residing in that the liquid core distortion, carried out between points S and L, be reducing the volume of the casting product, the length being equal (unchanged), whereas its lateral surface is maintained constant; in this case in fact there are neither stretching nor rolling action, in a true actual sense, involving a creep (slippage) of solid material, until we are in the presence of a viscous mass M inside the product itself, namely along the whole length l_m .

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In terms of cross-section (the length in fact doesn't have any impact, as it is kept constant), the area of the cross-section has to be reduced, whereas its perimeter is approximately kept constant.

- 5 The following distortions will therefore be possible:
- from round product to square product (billets) or to rectangular product (blooms); or
 - from square billets to rectangular blooms; or, at last
 - from a certain bloom to a more flattened product
- 10 (bloom or slab), namely a product showing a higher ratio between the different sides.

From a theoretical point of view, there would be possible even a distortion involving the conversion of a casting cross-section having n sides to a distorted

15 cross-section having, at the end of the metallurgical length, $n-1$ sides, even if such hypothesis has poor chances to be reduced to practice.

It has to be underlined that should the distortion occur without the fulfilment of such a condition, the volume would increase or would at the most remain at a

20 constant level; there would therefore fail the presupposition for obtaining the desired features hereinabove, allowing the product to be directly conveyed to the finishing rolling, without any intermediate operative

25 step, as it is already endowed with all the features of the desired semifinished product.

As it was already said, the distortion according to the instant invention can occur all along the metallurgical length, starting from point S, but preferably inside a

30 limited zone thereof; this latter can be defined as the zone corresponding to the 10-80% of the percentage con-

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centration x of solid grains in the mass M , which can be easily determined if we take into account that $x_S=0$ and that $x_L=100$. Therefore if l_S is the distance of S from l_0 , the x_l concentration in a whatsoever point far
 5 l from l_0 is:

$$x = \frac{l - l_S}{l_m}$$

It can be useless in fact to carry out the distortion
 10 with volume reduction in a too high zone of the casting, where the concentration of the solid grains is least and the grains themselves couldn't be affected, because of their dispersion in the liquid mass, by the mechanical action exerted by the solidified walls P .

15 From the other side, it can even be a drawback to perform the distortion in the lowermost zone, in the proximity of point L , where the walls P are already so near as to easily build up a few weldings and consequently a few pockets containing liquid material which,
 20 by solidification and consequent volume shrinking, would give rise to cavities inside the product, which drawback has preferably to be avoided.

Referring to Fig. 2, there is represented, in an extremely schematic way, an apparatus fit for carrying
 25 out the process according to the invention, as it is shortly described hereinbelow. The product 1, contained in the ingot mold 10, descends, through the so called "foot rolls" 11 along the roller train 13, defined by pairs of opposed sectors of roller cages 12, 14, 12',
 30 14' and so on. The first sector, immediately after the foot rolls 11, where it is believed sufficient, in cer-

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tain cases, to limit the volume reducing distortion according to the present invention, is usually called "segment zero". Sectors 12, 12', 12'' and so on are all lying on the extrados of the curvilinear axis, namely they have a greater bending radius, whereas sectors 14, 14' and so on are defined intrados segments. The rolls of sector 12 are represented by the reference number 12a and the ones of sector 14 by the reference number 14a and so on.

According to the instant invention and to the hypothesis above, according to which the distortion according to the invention is determined by said first sector, the intrados portion 14 is made to be mobile with respect to the extrados 12 in whatsoever known way, there being provided means 16 for drawing cage 14 near the opposite cage 12, which remains motionless. As it is reported on Fig. 2, the cage or bearing structure 14, comprising rolls 14a, is pivoted in 15 at one of its ends, preferably the superior one, and a hydraulic piston 16 pushes the opposite end of the intrados structure towards the motionless extrados 12. Of course, there can be provided whatsoever other solution of the problems, known to the skilled in the art; it is thus possible, for instance, to let the intrados sector 14 slide along a skid device and to provide one or more hydraulic pistons for the thrust along the same skid device. In any case, an apparatus of this kind can be used when a square product or billet has to be converted into a bloom or when an already rectangular product, like a bloom, has to be converted into an always rectangular however more flattened shape, for instance

a (thick) slab.

Should on the contrary a round product be converted, by means of distortion, into a product showing a square or rectangular cross-section, it is no more sufficient to work in the plane of Fig. 2, but a corresponding action has to be contemporaneously carried out in a plane normal to the plane above, always containing the casting axis X-X, as it is recorded on the section view of Fig. 3. In this case the distortion of a round product 1 is contemporaneously caused by two pairs of rolls, lying in diametrically opposed positions of the perimeter of the same round product, namely rolls 12a and 14a of the opposite extrados and intrados cages 12 and 14, recorded on Fig. 2, as well as rolls 22a and 24a, respectively belonging to roll cages not reported in Fig. 2, having the opposite rolls oriented normally to the rolls 12a and 14a of cages 12 and 14.

Preferably the subsequent rolls, downstream of the ones arranged in the sector undergoing distortion, are supplied with pistons fit for exerting a thrust towards the inside of the casting, no more for distortion purposes but for opposing the ferrostatic pressure and the possible consequent swelling, which can occur between the contact with a roll and the subsequent one, thus fitting to the size reached in the preceeding distortion phase.

EXAMPLE

From a continuous casting ladle, having a round cross-section, it was cast, with a progression speed $V=2\text{m/min.}$, a round product (rod) having a diameter of 130 mm. In a zone between 28% and 76% of the concentra-

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tion of the solid grains and by a metallurgical length equal (in this case) to 8 m, there was caused a distortion leading to a substantially square billet having a 100 mm side.

- 5 Subsequently the same rod was converted in another billet, having a similar size, however increasing the speed up to 3 m/min., and the distortion, according to the description above, was made to occur in a zone between the concentration values x equal to 14% and 46%,
10 whereas the metallurgical length was 12 m.

In both the cases there were sampled specimens of the cast product, once solidification was over, thus finding, by macrographic analysis, the following results:

- a) fine structure, without dendritic evidence;
- 15 b) structure isotropy, without any main orientation of the grains;
- c) absence of (kish) segregations, with homogeneity, in terms of chemical analysis, all along the cross-section;
- 20 d) isotropy of the mechanical features (tensile strength, yield point, break elongation, impact strength);
- e) better mechanical features, with respect to the product coming from a traditional casting, such as to al-
- 25 low the reaching of the same end features of the end product with lower percentages of reduction in the rolling step.

From the above it is clear that the apparatus according to the instant invention allows the product, coming
30 from the continuous casting and handled according to the process above, to be directly conveyed to a fini-

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shing rolling mill, by merely interposing a heating oven, optionally an induction oven, for adjusting the temperature according to the rolling values.

Optional additions and changes can be carried out by
5 the skilled in the art, as to the process according to the instant invention hereinabove, as well as modifications of the described and illustrated apparatus for carrying out such process, without exceeding the scope of the same invention.

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C L A I M S

1. A process for the manufacture of billets and blooms from a continuously cast steel showing high or excellent quality, comprising a liquid core distortion step for the casting product, causing a reduction of the cross-section of the product, the perimeter of said section being equal, in the route between point (S); namely the lowermost point on the casting axis (X-X) where the superheated liquid is still present, and the end (L) of the metallurgical length (l_m) where the product is completely solidified.
2. A process according to claim 1, wherein said liquid core distortion step is occurring in a zone of the continuous casting route comprised between points corresponding to a concentration of the solid grains, inside the liquid core (M) respectively equal to 10% and to 80%.
3. A process according to claim 1 or 2, comprising the distortion of a round casting product (rod) to a square or rectangular product.
4. A process according to claim 1 or 2, comprising the distortion of a square casting product to a rectangular product.
5. A process according to claim 1 or 2, comprising the distortion of a rectangular casting product to an always rectangular section having a ratio between the different sides farther from 1.
6. An apparatus for the continuous casting of steels, comprising a ladle (10), foot rolls (11) and opposite sectors of a curvilinear roller train (13), respectively extrados (12, 12'...) and intrados (14, 14'...),

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wherein at least one of said intrados sectors is mobile and wherein there are means (16) fit for bringing said sector to the opposite one.

7. An apparatus according to claim 6, wherein said mobile sector is the first intrados sector (14) after the ladle (10), pivoted in (15) at its uppermost end and connected, at its lowermost end, to the working piston of a hydraulic cylinder (16) which can be operated from outside.

8. An apparatus according to claim 6 or 7, furtherly comprising roll cages (22, 24) fit for defining, between each other the same roller train (13) with rolls (22a, 24a) normal to the rolls (12a, 14a) of the sectors (12, 12', 14, 14'), wherein the cages corresponding to said mobile intrados sectors (14) are too arranged in a mobile way, wherein there are provided means fit for pushing said cages (22, 24) and for bringing the same cages near each other, normally to the movement direction of said mobile sectors (14).

9. An apparatus according to claims 6-8, wherein the rolls (12'a, 12''a...; 14'a, 14''a...) of the sectors of the roller train downstream of the mobile sector are each supplied with pistons fit for exerting a thrust towards the inside of the casting (1), for opposing the ferrostatic pressure of the same casting and thus for fitting to the size reached in the preceeding distortion step.

10. An apparatus according to whatsoever of the claims 6-9, directly connected to a finishing rolling mill, there being merely interposed an oven optionally an induction oven, for bringing the temperature back to the

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values fit for the rolling step.

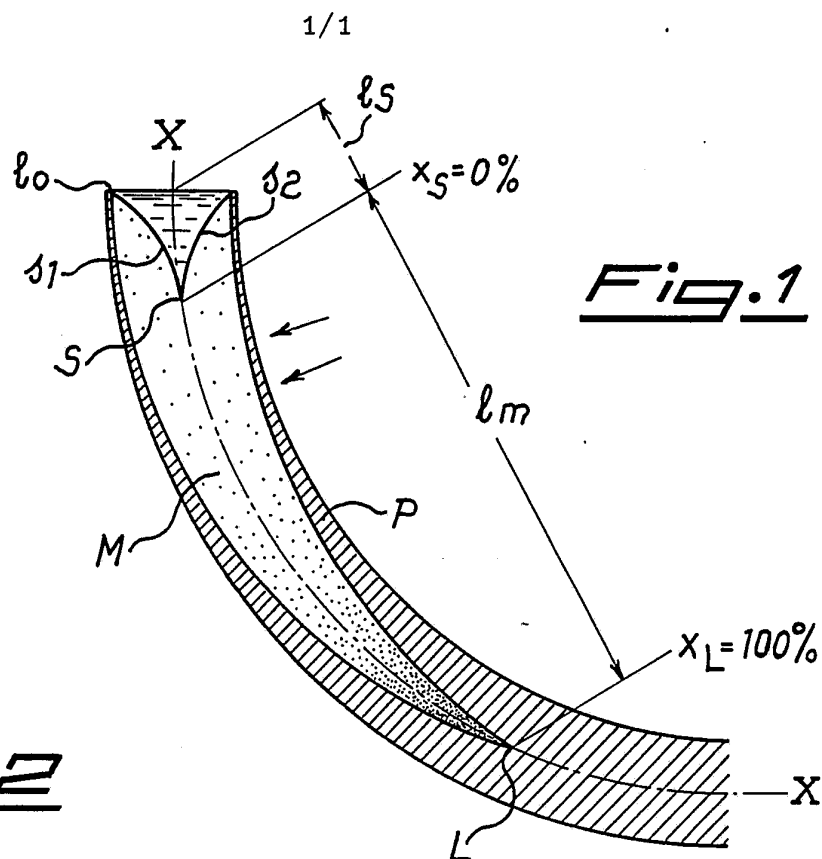


Fig.1

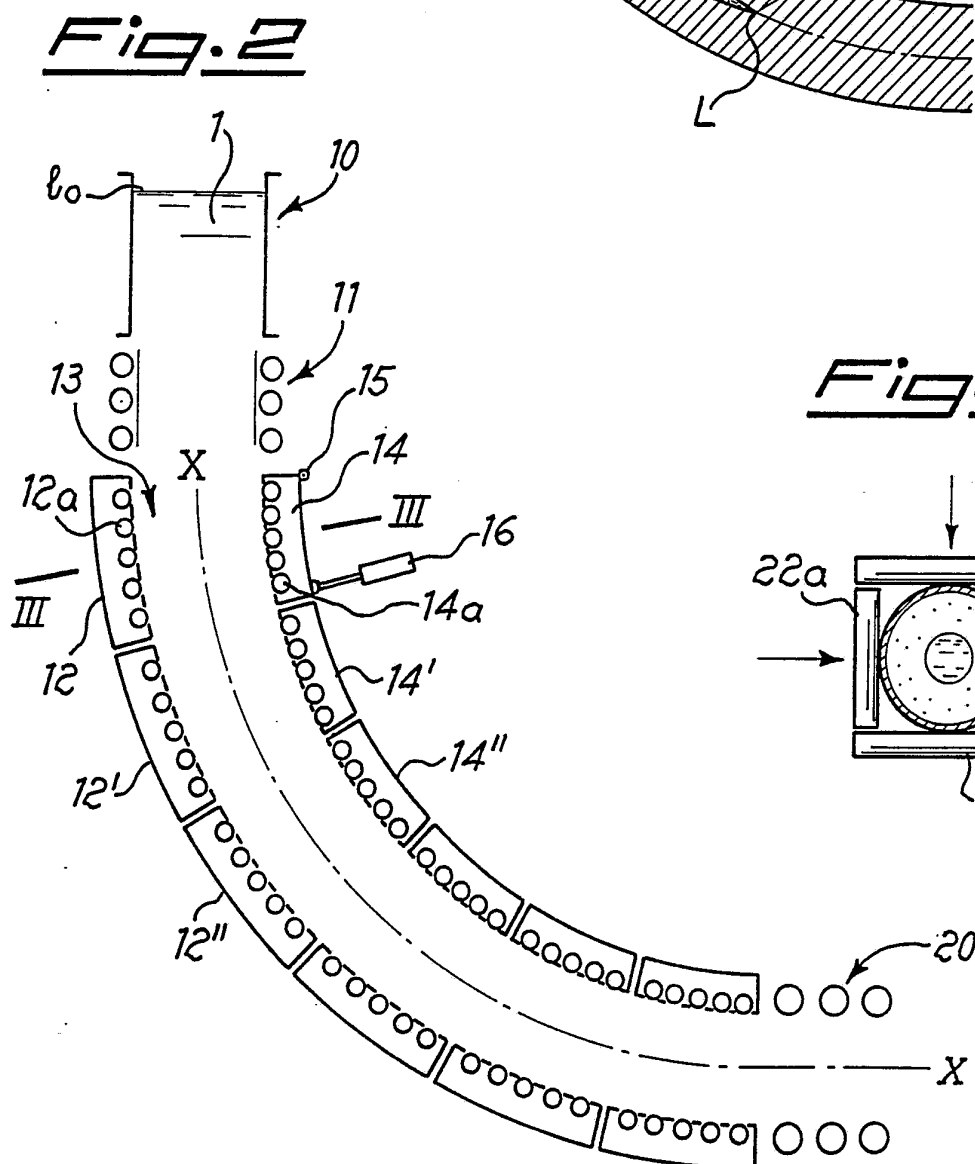
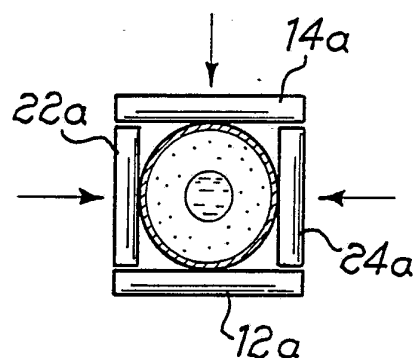


Fig. 3



INTERNATIONAL SEARCH REPORT

PCT/IT 92/00113

International Application No

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC Int.Cl. 5 B22D11/12		
II. FIELDS SEARCHED		
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Int.Cl. 5	B22D ; B21B	
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III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	US,A,3 478 809 (B. TARMANN ET AL) 18 November 1969 ----	
A	PATENT ABSTRACTS OF JAPAN vol. 12, no. 437 (M-765)(3284) 17 November 1988 & JP,A,63 171 255 (SUMITOMO METAL IND LTD) 15 July 1988 see abstract ----	
A	EP,A,0 391 824 (TECHMETAL PROMOTION) 10 October 1990 ----	
A	WO,A,8 912 517 (DAVY LTD) 28 December 1989 -----	
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IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
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International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	HODIAMONT S.	

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IT 9200113
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