(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 502 344 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **92102406.3**

(51) Int. Cl.5: **B22D 11/01**, B22D 11/06

(22) Date of filing: **13.02.92**

(30) Priority: **06.03.91 SE 9100662**

(43) Date of publication of application:
09.09.92 Bulletin 92/37

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IT LI LU NL PT SE

(71) Applicant: **Tetra Alfa Holdings S.A.**
70, Avenue Général-Guisan
CH-1009 Pully(CH)

(72) Inventor: **Ignell, Rolf**
Chemin de Mourex, Grilly
F-01220 Divonne-Les-Bains(FR)

(74) Representative: **Müller, Hans-Jürgen et al**
Patentanwälte, Dipl.-Ing. Hans-Jürgen Müller, Dipl.-Chem.Dr. Gerhard Schupfner, Dipl.-Ing. Hans-Peter Gauger, Postfach 101161
W-8000 München 1(DE)

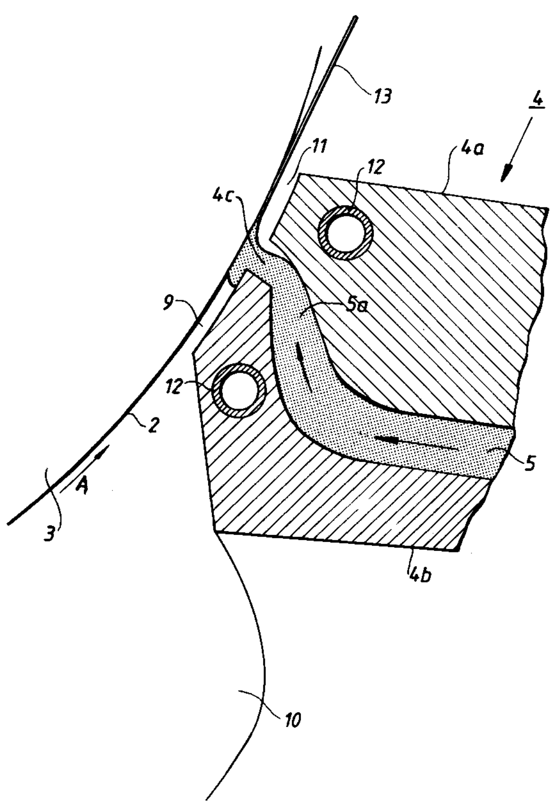
(54) **An apparatus for producing web-shaped metal foil.**

(57) The disclosure relates to an apparatus for producing a web-shaped metal foil (13) from molten starting material. The apparatus includes a movable, cooled substrate (3) and a nozzle (4) discharging a short distance from the substrate, by means of which nozzle the molten material is disposed to be applied to the substrate for cooling, for the formation of the web-shaped foil.

In order to ensure good contact between the molten material and the substrate, the apparatus has a space (9) disposed between the nozzle (4) and the substrate (3), the space being connected to a vacuum chamber (10) in order, with the aid of a vacuum established in the space (9), to suck the molten material towards the substrate at constant, sufficiently high pressure so as to displace interface layers of air accompanying the substrate.

In one alternative embodiment, the apparatus may be provided with a space disposed between the nozzle (4) and the substrate (2), the space being communicable with a pressure chamber (instead of the above-mentioned vacuum chamber) in order to press, by means of pressure, the molten material supplied through the nozzle against the substrate.

Fig.2



EP 0 502 344 A1

The present invention relates to an apparatus for producing metal foil from molten starting material, the apparatus including a movable, cooled substrate and a nozzle discharging a short distance from the substrate, by means of which nozzle the molten material is disposed to be applied to the substrate for cooling, for the formation of the metal foil.

BACKGROUND ART

An apparatus of the type described above is previously known from, for example, US-A-4,142,571. The prior art apparatus has a nozzle directed towards the circumferential surface of a rotary roller or drum, the opening of the nozzle located a short distance from the circumferential surface being connected to a reservoir for heated molten metal material disposed above the nozzle through a slot-shaped nozzle channel connecting the nozzle opening and the reservoir. The reservoir is connected to a pressure source by means of which molten material may be urged from the reservoir through the nozzle channel and the nozzle opening out onto the circumferential surface for cooling, for the formation of a metal foil.

It is known that the quality of a metal foil which is produced in accordance with the above-described so-called Planar Flow Casting technique is greatly dependant upon and varies with fluctuations in the cooling cycle of the melt. In order to achieve the desired uniform foil quality, it is thus important that the cooling cycle of the melt take place under as constant conditions as possible. In this instance, a key factor is the interface layer of air which accompanies the substrate and which may readily give rise to air pockets between the melt and the substrate which disrupt the cooling cycle and are thereby detrimental to quality. In order to avoid or minimize the risk of quality deterioration caused by such air pockets, the air interface must, therefore, be displaced, which, in the prior art apparatus, is achieved partly by the proximity of the nozzle opening to the substrate and partly by the pressure of the melt forced through the nozzle opening against the substrate. Since the melt pressure against the substrate displacing the interface layer of air in a given nozzle design (the slot width of the nozzle channel and nozzle opening) is, in all essentials, dependant upon the pressure applied to the molten material in the reservoir, the applied pressure must, hence, be kept above a certain minimum pressure level in order to achieve the desired air displacement. Since the applied pressure, in a given nozzle design, also influences the quantity of positively discharged melt and ultimately the thickness of the finished foil, the pressure should, moreover, be kept as constant as possible in order to ensure a uniform foil thickness.

However, the problem inherent in the prior art apparatus is that it is difficult to avoid pressure variations, for example in connection with replenishment of the reservoir, which results in corresponding thickness variations in the foil. Another problem inherent in the prior art apparatus is that it does not wholly unconditionally make for the production of metal foils of thicknesses below a certain value, eg. 50 µm. As has been explained above, the thickness of the metal foil in a given nozzle design is, in all essentials, dependant upon the pressure which is applied to the molten material in the reservoir and which in turn determines the quantity of extruded melt. In increased quantities of discharged melt, the foil thickness increases, while consequentially diminishing at the same rate as the quantity of dischargedmelt is reduced. Thus, when the apparatus is to be switched from producing a metal foil of a certain thickness to producing a metal foil of another, slighter thickness, the applied pressure (and thereby the quantity of discharged melt) must thus be reduced correspondingly. Such a pressure reduction entails, at the same time, that the melt pressure against the substrate which displaces the interface air layer is reduced, with resultant increased risk of air pockets between the melt and the substrate, which disrupt the cooling process and thereby impair the quality of the finished foil. In order to prevent the reduced melt pressure against the substrate from being lower than is required for achieving desired air displacement as explained above, a modification of nozzle design (i.e. nozzle channel and nozzle opening with smaller slot width) is thus required in the prior art apparatus in order to be able to reduce the discharged quantity of melt to an extent adapted to the desired foil thickness. However, a nozzle design with reduced slot width of nozzle channel and nozzle opening is highly sensitive to and places great demands on the purity of the molten starting material which should, therefore, be pure and wholly free of large-sized impurities in order to be able to pass through the nozzle channel and nozzle opening without becoming stuck and clogging the passage. Consequently, using the prior art apparatus, it is not possible to produce a metal foil of a thickness of less than 50 µm, for example 10-20 µm, without employing an extremely pure - and thereby expensive - starting material, which is a contributory factor in drastically raising the price of the finally produced metal foil.

OBJECTS OF THE INVENTION

One object of the present invention is, therefore, to propose an apparatus of the type described by way of introduction which permits production of a metal foil of desired large (eg. 50 µm) or lesser (eg. 10-20 µm) thickness and with uniform foil qualities without suffering from the consequential drawbacks of the type inherent in the prior art apparatus.

Another object of the present invention is to devize an apparatus of the described type which makes possible the production of an extremely thin (10-20 um) metal foil using the cheapest concievable starting material (metal scrap), without the risk of clogging of the channel and/or the opening in the nozzle employed.

SOLUTION

These and other objects will be attained according to the present invention in that an apparatus of the type described in the foregoing has been given the characterizing feature that a space defined between the substrate and the nozzle is communicable with a vacuum chamber or a pressure chamber, by means of which molten material supplied through the nozzle is disposed to be sucked or pressed, respectively, into contact with the substrate.

With the aid of the pressure difference created by the vacuum chamber or the pressure chamber, respectively, in the space between the substrate and the nozzle, it is thus possible to maintain a sufficiently high, constant melt pressure against the substrate, i.e. a melt pressure which is wholly independent of both the quantity of the melt supplied through the nozzle opening and any possible pressure variations occurring in the inflowing melt. The constant melt pressure realized by the pressure difference creates extraordinarily good pre-conditions for producing a metal foil of uniform superior surface qualities, at the same time as naturally also contributing to enhancing the efficiency of contact between the melt and the substrate, and thereby the cooling cycle of the melt. A further advantage afforded is that the melt pressure against the substrate may be kept constant irrespective of the quantity of melt which is supplied, which implies that metal foils of different, both large and small thicknesses, may be produced without the need for modifying the design of the nozzle (the slot width of the nozzle channel and the nozzle opening). Hence, metal foils of very large thicknesses, eg. above 50 µm, as well as metal foils of very slight thicknesses, eg. 10-20 µm, may be produced employing one and the same nozzle design. In particular, this entails that the slot width of the nozzle channel and nozzle opening may be very large, of the order of 2-3 mm, for which reason the nozzle will be less sensitive, or completely insensitive, to the purity of the starting material employed, even if metal foils of very slight thicknesses (10-20 µm) are to be produced.

Further practical and advantageous embodiments of the apparatus according to the present invention have moreover been given the characterizing features as set forth in the appended subclaims.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

The present invention will be described in greater detail hereinbelow with particular reference to the accompanying Drawings, in which:

Fig. 1 schematically illustrates in partial section an apparatus according to one embodiment of the invention;

Fig. 2 schematically illustrates, on a larger scale, the region of the nozzle opening in the apparatus of Fig. 1; and

Fig. 3 schematically illustrates, on a larger scale, the region of the opening of a nozzle according to another preferred embodiment of the apparatus according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

The apparatus according to the present invention which is schematically illustrated in partial section in Fig. 1 has been given the generic reference numeral 1. The apparatus 1 includes a movable, cooling substrate which, in the illustrated embodiment, consists of the circumferential or casing surface 2 of a roller or drum 3 rotary about a horizontal axis in the direction of the arrow A. Adjacent the roller 3, there is disposed a nozzle 4 comprising an upper and a lower nozzle lip 4a and 4b, respectively, which therebetween form the forward end 5a of a nozzle channel 5 which, at the forward end, discharges in a slot-shaped nozzle opening 4c (slot width 2-3 mm) directed towards the circumferential surface 2. The nozzle channel 5 is in communication with a reservoir 6 for molten starting material 7, eg. metal scrap, and is provided with a rear portion 5b extending beyond the reservoir 6 and being closed by means of an openable hatch or door 8.

As is apparent from Fig. 1, the nozzle 4 is arranged so that the nozzle channel 5 inclines somewhat upwardly towards the roller 3 in relation to the horizontal plane, as is intimated by the angle of inclination α marked at the rear region of the nozzle. The nozzle 4 is further arranged so that the nozzle opening 4c discharges a very short distance (approx. 0.3 mm at the lower nozzle lip 4b and the upper nozzle lip 4a) from the circumferential surface 2 in a region and on a level below the horizontal axis of rotation (not shown) of the roller 3, i.e. in a region located within the fourth quadrant of a coordinate system with zero point in the axis of rotation of the roller.

In order to make possible run-off of the molten material 7 from the reservoir 6 via the inclining nozzle channel 5, 5a out through the nozzle opening 4c by force of gravity, the reservoir 6 is kept filled to such an extent that the surface of the molten material in the reservoir lies at a level (h) above the nozzle opening 4c. According as the reservoir 6 is emptied, the surface sinks and, in order to prevent the surface from sinking to a level flush with the nozzle opening 4c (i.e. h = 0), the reservoir 6 is disposed to be replenishable with new molten material from a tiltable smelting furnace (not shown) disposed above the reservoir.

As is apparent from Fig. 2, which schematically illustrates the region of the nozzle opening 4c on a larger scale, there is provided, between the forward end of the lower nozzle lip 4b and the circumferential surface 2, a space 9 which is in communication with or communicable with a vacuum chamber 10. In the illustrated embodiment, the space 9 is of elongate, slot-shaped design with a substantially constant slot width (approx. 0.3 mm) throughout its entire axial extent. There is further provided, between the circumferential surface 2 and the forward end of the upper nozzle lip 4a, a slot-shaped elongate space 11 of the same slot width (i.e. approx. 0.3 mm) as the space 9. In order to maintain the molten material 7 at a constant temperature above the melting point of the material (eg. 950°C) throughout the entire passage through the channel 5 from the reservoir 6 to the nozzle opening 4c, heating devices 12, for instance glowing kanthal tubes, are provided in both the upper and lower nozzle lips 4a, 4b, respectively, by means of which tubes the molten material is prevented from cooling before exiting from the nozzle 4.

Fig. 3 shows the discharge portion of a nozzle according to another embodiment of the present invention and, for purposes of clarity, the same reference numerals as in Fig. 2 have been employed for corresponding parts, with the addition of a primo symbol. The nozzle 4' in Fig. 3 thus includes an upper and a lower nozzle 4a' and 4b', respectively, which therebetween define a nozzle channel 5'. Between the forward end of the lower nozzle lip 4b' and the surface 2' of the substrate, there is provided a similarly elongate space 9' which is in communication with or communicable with a vacuum chamber 10'. The space 9' differs from the space 9 of Fig. 2 in that it displays a rearwardly tapering (seen in the direction of movement of the substrate) or v-shaped cross section, i.e the distance between the nozzle lip 4b' and the circumferential surface 2' (the slot width) diminishes in a direction from the nozzle opening 4c' and rearwardly. The space 11' between the upper nozzle lip 4a' and the surface 2' is, on the other hand, substantially of constant slot width throughout its entire axial extent.

The apparatus 1 in Figs. 1 and 2 produces a web-shaped metal foil 13 in the following manner. The space 9 is placed in communication with the vacuum chamber 10 and molten material 7 runs by force of gravity from the reservoir 6 through the nozzle channel 5 out through the nozzle opening 4c for forming a so-called melt puddle 7' in the region of the nozzle opening. Because of the pressure (eg. 70-90cm water column) which prevails in the space 9, the rear portion of the melt puddle will be sucked into the space 9 and thereby against the circumferential surface 2 at constant, sufficiently high pressure to displace the interface layer of air which accompanies the circumferential surface moving in the direction of the arrow A (eg. at 30 m/s). On contact with the cooling (approx. 170°C) substrate, the melt puddle is cooled from beneath for the formation of a metal foil 13 accompanying the circumferential surface 2, the metal foil being, after passage through the space 11, unwound from the circumferential surface and wound up into a roll of foil.

Using the apparatus 1, metal foils may be produced in this manner with varying, but in every individual case uniform thicknesses and of uniform superior surface qualities. If, for example, a metal foil of a given thickness (50 µm) is desired, the quantity of supplied melt is correspondingly regulated, while, if a metal foil of a lesser thickness (10-20 µm) is to be produced, a correspondingly reduced quantity of melt is supplied. The quantity of melt which is supplied in each individual case is, to all essentials, determined by the level difference (h) between the surface of the melt in the reservoir 6 and the nozzle opening 4c, which is easy to regulate by the controlled supply of new melt from the smelting furnace (not shown).

In a corresponding manner, a metal foil 13' is produced using the nozzle 4' illustrated in Fig. 3. The advantage inherent in this nozzle is that the vacuum in the space 9' need not be of such magnitude as the corresponding vacuum in the space 9 to achieve the contemplated sufficiently high melt pressure against the circumferential surface 2', since the tapering cross section of the space gives rise to a pressure composant directed towards the circumferential surface and increasing in a direction rearwardly from the nozzle opening 4c'. In the same manner as using the nozzle 4, the nozzle 4' can be instrumental in producing metal foils of varying, but in each individual case uniform thicknesses and of uniform superior surface qualities. For example, a metal foil may be produced of a thickness of approx. 50 µm by the supply of a certain adapted quantity of molten material, while a thinner metal foil, eg. of the order of 10-20 µm, is produced in that the quantity of supplied molten material is kept at a correspondingly lower level.

It should finally be observed that the apparatus according to the present invention may, instead of the vacuum chamber described in the foregoing and specifically shown on the Drawings, be provided with a pressure chamber between the nozzle and the substrate, in order to press the melt at constant pressure against the substrate. The pressure chamber should ideally be disposed ahead of the melt supplied through the nozzle (seen in the direction of movement of the substrate). Thus, according to the present invention, the constant high melt pressure against the substrate is catered for by the pressure difference which the apparatus creates between the nozzle and the substrate and which is either achieved by means of the space communicable with the vacuum chamber or the space communicable with the pressure chamber, as described above.

As will be apparent from the foregoing description, it is possible, according to the present invention, to produce, from molten starting material, both thick and thin metal foils using an apparatus which is extremely simple in both design and operative mode and which, in particular, makes it possible to produce extremely thin metal foils (10-20 μm) employing the cheapest possible starting material, for example metal scrap, without the risk of clogging of the nozzle channel and/or nozzle opening because of particles present in the starting material.

The present invention should not be considered as restricted to that described above and shown on the Drawings, many modifications being conceivable without departing from the spirit and scope of the appended Claims.

Claims

1. An apparatus for the production of web-shaped metal foil (13; 13') from molten starting material (7), the apparatus including a movable, cooling substrate (2; 2') and a nozzle (4; 4') discharging a short distance from the substrate and by means of which the molten material is disposed to be applied to the substrate for cooling, for the formation of the metal foil, **characterized in that** it is provided, between the nozzle (4; 4') and the substrate (2; 2'), with a space (9; 9') which, for the purpose of creating a pressure difference between the substrate and the molten material supplied through the nozzle, is communicable with a vacuum chamber (10; 10') or a pressure chamber in such a manner that the molten material is pressed against the substrate by this pressure difference.

2. The apparatus as claimed in Claim 1, **characterized in that** the space (9; 9') is elongate, with the longitudinal axis of the space substantially parallel to the substrate.

3. The apparatus as claimed in Claim 2, **characterized in that** the space (9') tapers in a direction away from the opening (4c') of the nozzle.

4. The apparatus as claimed in any one of the preceding Claims, **characterized in that** the substrate (2') consists of the circumferential surface of a rotary roller or drum (3).

5. The apparatus as claimed in Claim 4, **characterized in that** the nozzle (4; 4') is disposed at a level beneath the axis of rotation of the roller.

6. The apparatus as claimed in any one of the preceding Claims, **characterized in that** the nozzle (4; 4') includes an upper (4a; 4a') and a lower (4b; 4b') lip which together define a nozzle opening (4c; 4c') directed towards the substrate (2; 2'), the space (9; 9') communicable with the vacuum chamber (10; 10') being disposed between the substrate and the lower lip.

7. The apparatus as claimed in Claim 6, **characterized in that** the distance between the substrate (2; 2') and the lower lip (4b; 4b') is less than the distance between the substrate and the upper lip (4a; 4a').

8. The apparatus as claimed in Claim 6 or 7, **characterized in that** both the upper and the lower nozzle lips include heating devices (12; 12') for maintaining the nozzle (4; 4') at a temperature in excess of the melting temperature of the starting material.

9. The apparatus as claimed in any one of the preceding Claims, **characterized in that** the portion of the channel disposed towards the reservoir (6) has a rear section extending beyond the reservoir and closed by means of an openable hatch or door (8).

Fig.1

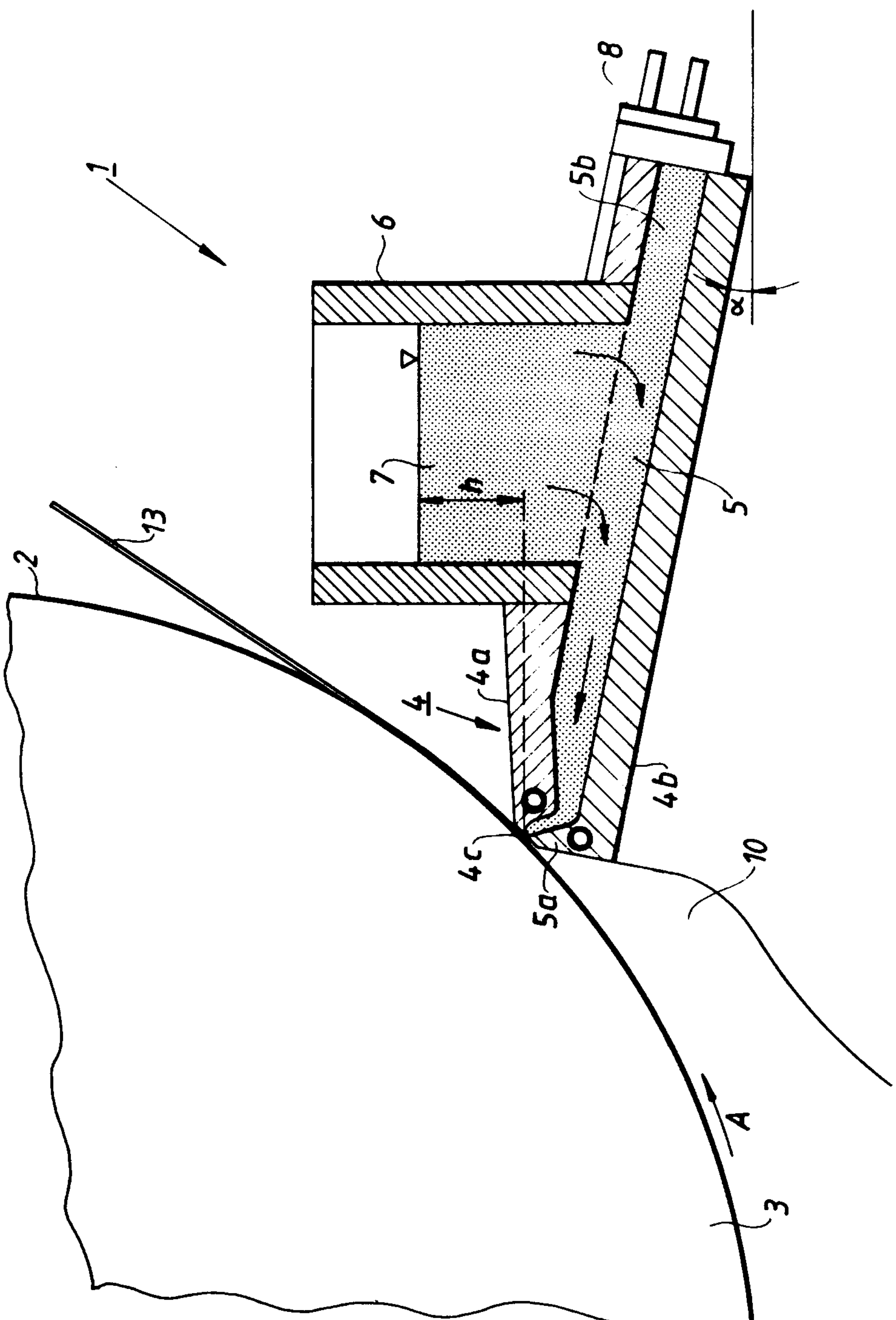


Fig.2

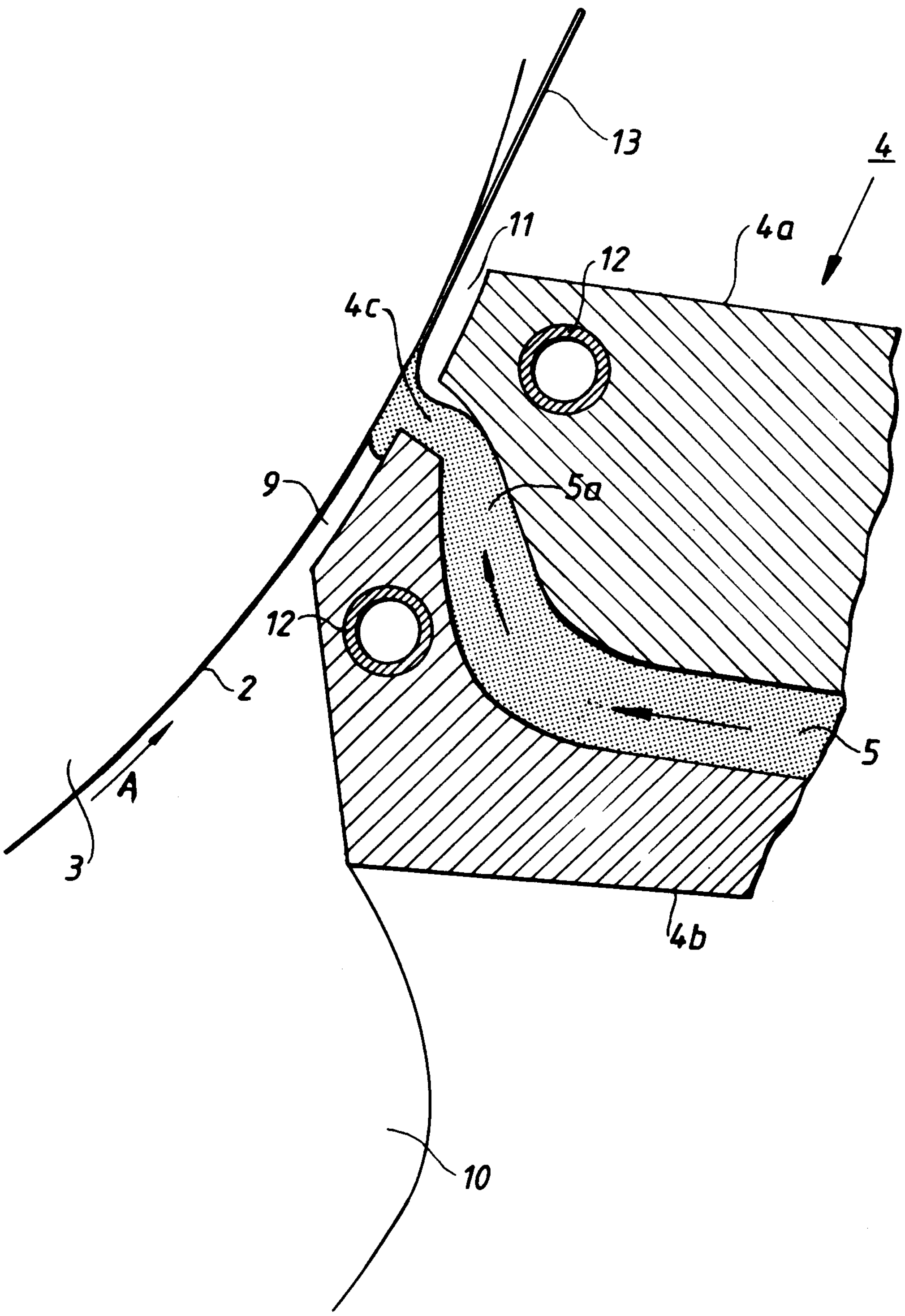
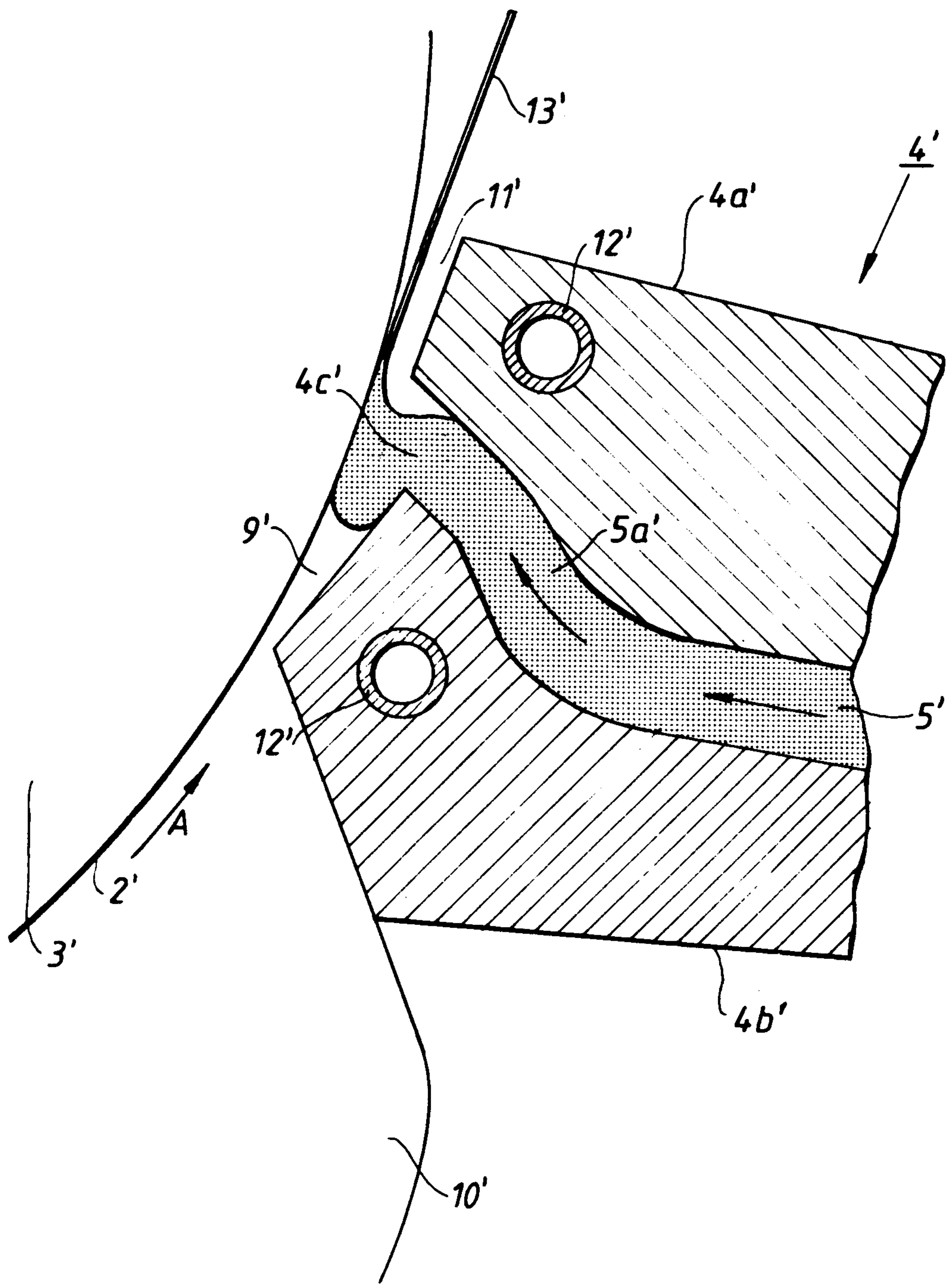


Fig.3



European Patent Office

EUROPEAN SEARCH REPORT

Application number
EP 92 10 2406.3

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl⁵)
X	US-A-4 649 984 (JOHN R. BEDELL et al) * Figures 1-5; abstract * ---	1,4	B 22 D 11/01 B 22 D 11/06
X Y	EP-A-0 208 890 (SUNDWIGER EISENHÜTTE MASCHINENFABRIK GRAH & CO) * Figures 3-5; claims 19, 25 * ---	1-4,6, 7 9	
X	PATENT ABSTRACT OF JAPAN, Vol. 5, No. 53 (M-63), 29 January 1981; & JP-A- 56-9046, (HITACHI SEISAKUSHO K.K.) ---	1,4,5	
X	DE-C-2 950 406 (HITACHI, LTD. et al) * Column 4, line 12 - line 22; figures 1-2 * ---	1,4,8	
Y	DE-C-2 825 360 (FRIED. KRUPP GMBH et al) * Column 3, line 44 - line 47; figure 2 * ---	9	TECHNICAL FIELDS SEARCHED (Int Cl⁵) B 22 D
X	PATENT ABSTRACT OF JAPAN, Vol. 10, No. 47, (M-456), 9 October 1985; & JP-A- 60-199552, (CHIN NIPPON SEITETSU K.K.) -----	1,2	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
STOCKHOLM	27-05-1992	NYSTRÖM U.

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

EPO Form 1503 03 82