Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 3045969 C 2021/07/27

(11)(21) **3 045 969**

(12) BREVET CANADIEN
CANADIAN PATENT

(13) **C**

(86) **Date de dépôt PCT/PCT Filing Date:** 2016/12/30
(87) **Date publication PCT/PCT Publication Date:** 2018/07/05
(45) **Date de délivrance/Issue Date:** 2021/07/27
(85) **Entrée phase nationale/National Entry:** 2019/06/03
(86) **N° demande PCT/PCT Application No.:** IB 2016/058115
(87) **N° publication PCT/PCT Publication No.:** 2018/122591

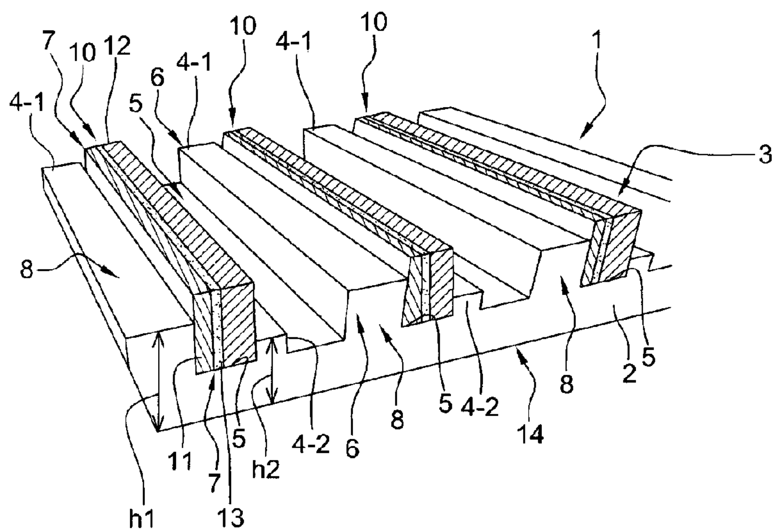
(51) **Cl.Int./Int.Cl.** *C21B 7/10* (2006.01), *F27B 1/24* (2006.01), *F27B 3/24* (2006.01), *F27D 1/12* (2006.01)

(72) **Inventeur/Inventor:**
HERRERO BLANCO, IGNACIO, ES

(73) **Propriétaire/Owner:**
ARCELORMITTAL, LU

(74) **Agent:** SMART & BIGGAR LLP

(54) Titre : PLAQUE DE REFROIDISSEMENT EN CUIVRE DOTEE DE PROTUBERANCES MULTICOUCHE COMPRENANT UN MATERIAU RESISTANT A L'USURE, DESTINEE A UN HAUT-FOURNEAU
(54) Title: COPPER COOLING PLATE WITH MULTILAYER PROTRUSIONS COMPRISING WEAR RESISTANT MATERIAL, FOR A BLAST FURNACE



(57) **Abrégé/Abstract:**
The invention relates to a cooling plate (1) for use in a blast furnace. This cooling plate (1) comprises a copper body (2) having an inner face (3) comprising ribs (4-1, 4-2)parallel therebetween, having first extremities(6) and separated by grooves (5)having second extremities(7). At least one of these grooves (5)comprises at least a part of a multilayer protrusion (10) extending between its second extremities (7) and comprising at least one layer (12) made of a wear resistant material that increases locally the wear resistance of the neighboring ribs (4-1, 4-2).

CA 03045969 2019-06-03

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
05 July 2018 (05.07.2018)

(10) **International Publication Number**
WO 2018/122591 A1

(51) **International Patent Classification:**
C21B 7/10 (2006.01) ***F27B 3/24*** (2006.01)
F27B 1/24 (2006.01) ***F27D 1/12*** (2006.01)

(21) **International Application Number:** PCT/IB2016/058115

(22) **International Filing Date:** 30 December 2016 (30.12.2016)

(25) **Filing Language:** English

(26) **Publication Language:** English

(71) **Applicant: ARCELORMITTAL** [LU/LU]; 24-26 Boulevard d'Avranches, L-1160 Luxembourg (LU).

(72) **Inventor: HERRERO BLANCO, Ignacio**; ArcelorMittal Europe Flat Products, Oficinas Taller Central Verina, P.O. Box 570, 33280 Gijon - Asturias (ES).

(74) **Agent: PLAISANT, Sophie**; ArcelorMittal France, Immeuble Le Cézanne, 6, rue André Campra, F-93200 Saint-Denis (FR).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title:** COPPER COOLING PLATE WITH MULTILAYER PROTRUSIONS COMPRISING WEAR RESISTANT MATERIAL, FOR A BLAST FURNACE

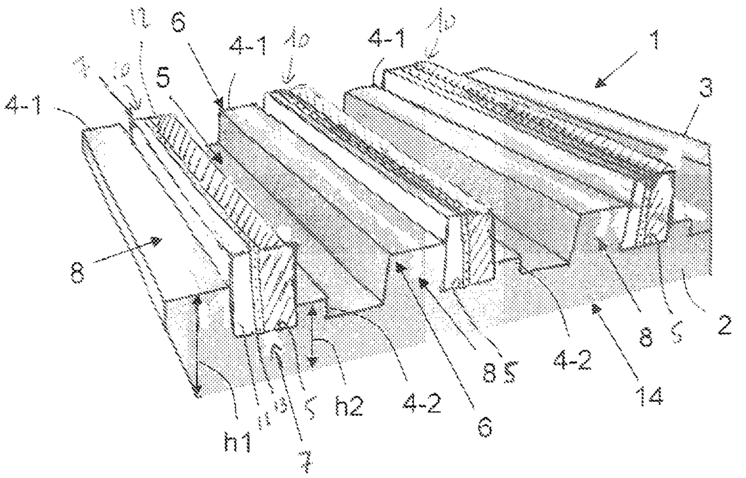


FIG.1

(57) **Abstract:** The invention relates to a cooling plate (1) for use in a blast furnace. This cooling plate (1) comprises a copper body (2) having an inner face (3) comprising ribs (4-1, 4-2)parallel therebetween, having first extremities(6) and separated by grooves (5)having second extremities(7). At least one of these grooves (5)comprises at least a part of a multilayer protrusion (10) extending between its second extremities (7) and comprising at least one layer (12) made of a wear resistant material that increases locally the wear resistance of the neighboring ribs (4-1, 4-2).

WO 2018/122591 A1

Copper cooling plate with multilayer protrusions comprising wear resistant material, for a blast furnace

[0001] The invention relates to blast furnaces, and more precisely to cooling plates (or staves) that are fixed into blast furnaces.

[0002] As known by the man skilled in the art, a blast furnace generally comprises an inner wall partly covered with cooling plates (or staves).

[0003] In some embodiments these cooling plates (or staves) comprise a body having an inner (or hot) face comprising ribs parallel therebetween and separated by grooves also parallel therebetween. These ribs and grooves are arranged for allowing anchorage of a refractory lining (bricks or guniting) or of an accretion layer inside the blast furnace.

[0004] When the body is made of copper or copper alloy, to offer a good thermal conductivity, the ribs are undergoing an early erosion because copper is not a wear resistant material.

[0005] To avoid such an early erosion, it is possible to increase the hardness of the ribs by introducing a steel piece in the grooves against the sidewalls of the ribs and the groove base, as described in the patent document EP 2285991. Such steel pieces allow a good protection of the ribs, and allow also the staves to expand and deform freely because they are thermally compatible with the stave deformations. But, they are not properly cooled and could be washed out by the gas.

[0006] So, an objective of the invention is to improve the situation.

[0007] To this end, the invention relates to a cooling plate (or stave) for use in blast furnace and comprising a copper body having an inner face comprising ribs parallel therebetween, having first extremities opposite therebetween and separated by grooves having second extremities opposite therebetween.

Date Reçue/Date Received 2020-12-03

[0008] This cooling plate (or stave) is characterized in that at least one of its grooves comprises at least a part of a multilayer protrusion extending between its second extremities and comprising at least one layer made of a wear resistant material that increases locally the wear resistance of the neighboring ribs.

[0009] The cooling plate (or stave) of the invention may also comprise the following optional characteristics considered separately or according to all possible technical combinations:

- the wear resistant material may be chosen from a group comprising a metal and a ceramic;
  - ➢ the wear resistant metal may be a wear-resistant steel or cast iron;
  - ➢ the wear resistant ceramic may be silicon carbide, an extruded silicon carbide or other refractory material with good resistance to spalling and high hardness;
- the multilayer protrusion may comprise a first layer made of a material having a high thermal conductivity, and a second layer made of the wear resistant material and set on top of the first layer;
  - ➢ the material of the first layer may be chosen from a group comprising a high conductivity metal copper and a copper alloy;
  - ➢ in a first embodiment each multilayer protrusion may be associated to a single groove;
    - • the multilayer protrusion may further comprise a third layer sandwiched between the first and second layers and made of a material having a hardness intended for increasing hardness of the multilayer protrusion;
      - o the third layer may be made of a ceramic with good resistance to spalling and high hardness, such as SiC or extruded SiC;
  - ➢ in a second embodiment the first and second layers of each multilayer protrusion may be respectively associated to two neighboring grooves;

- the first layer of each multilayer protrusion may comprise a slot extending between the second extremities and comprising an other insert made of a material having a hardness intended for increasing hardness of this first layer;

- the other insert may be made of a ceramic or of a wear-resistant and/or heat-resistant steel;

the inner face of the copper body may comprise ribs having at least two different heights;

- the grooves may have a dovetail cross-section.

[0010] The invention also relates to a blast furnace comprising at least one cooling plate such as the one above introduced.

[0010a] The invention also relates to a cooling plate for a blast furnace, said cooling plate comprising a copper body having an inner face comprising ribs parallel therebetween, having first extremities opposite therebetween and separated by grooves having second extremities opposite therebetween, wherein at least one of said grooves comprises at least a part of a multilayer protrusion extending between said second extremities and comprising at least one layer made of a wear resistant material that increases locally the wear resistance of neighboring ribs.

[0011] Other characteristics and advantages of the invention will emerge clearly from the description of it that is given below by way of an indication and which is in no way restrictive, with reference to the appended figures in which:

- figure 1 illustrates schematically, in a perspective view, a part of a first example of embodiment of a cooling plate according to the invention,

- figure 2 illustrates schematically, in a cross section view, a part of a second example of embodiment of a cooling plate according to the invention,

- figure 3 illustrates schematically, in a cross section view, a variant of the cooling plate illustrated in figure 2, and

- figure 4 illustrates schematically, in a cross section view, a part of a third example of embodiment of a cooling plate according to the invention.

[0012] The invention aims, notably, at proposing a cooling plate (or stave) 1 that can be used in a blast furnace and presenting an increased wear resistance.

Date Reçue/Date Received 2020-12-03

[0013] An example of embodiment of a cooling plate (or stave) 1 according to the invention is illustrated in figure 1. Such a cooling plate (or stave) 1 is intended to be mounted on an inner wall of a blast furnace.

[0014] As illustrated, a cooling plate (or stave) 1 according to the invention comprises a copper body 2 having an inner (or hot) face 3 comprising several ribs 4-j parallel therebetween. These ribs 4-j have first extremities 6 opposite therebetween and are separated by grooves 5 having second extremities 7 opposite therebetween. Once the cooling plate 1 is mounted on the blast furnace inner wall, its ribs 4-j and grooves 5 are arranged horizontally. In this case the copper body 2 comprises an outer face 14 that is opposite to its inner face 3 and fixed to the inner wall blast furnace. So, the inner face 3 is the body face that can be in contact with the very hot material and gas present inside the blast furnace.

[0015] For instance, and as illustrated in figures 2 to 4, the grooves 5 typically have a dovetail cross-section in order to optimize anchorage of refractory bricks 15. But, the ribs 4-j and grooves 5 may have other cross-section shapes.Although dovetail cross-section of the grooves 5 is preferred, in particular for receiving the multilayer protusions 10,as illustrated in figure 1, the grooves 5 may have a rectangular cross-section.

[0016] More, and as illustrated in the non-limiting example of figure 1, the inner face 3 of the copper body 2 may comprise ribs 4-j having at least two different heights h1 and h2. This option allows optimizing anchorage of refractory bricks 15. In the example of figure 1, first ribs 4-1 (j = 1) have a first height h1 and second ribs 4-2 (j = 2), defined between first ribs 4-1, have a second height h2 that is smaller than the first height h1. But, as illustrated in the other examples of embodiment of figures 2 to 4, the copper body 2 may comprise ribs 4-1 having the same height.

[0017] Still more, and as illustrated in figures 2 and 3, the copper body 2 comprises preferably internal channels 16 in which a cooling fluid flows.

[0018] As illustrated in figures 1 to 4, at least one of the grooves 5 comprises at least a part of a multilayer protrusion 10 extending between its second extremities

7 and comprising at least one layer 12 made of this wear resistant material that increases locally the wear resistance of the neighboring ribs 4-j.

[0019] Thanks to the multilayer protrusions 10 (located into grooves 5), the speed and pressure exerted by the descending burden on the stave are appreciably decreased, which allows avoiding an early erosion of their material (i.e. copper or copper alloy) and of the stave body.In other words, the protrusions allows generating an area of low material movement to minimize wear.

[0020] For instance, the wear resistant material of layer 12 may be a metal or a ceramic. This wear resistant metal may be, for instance a steel or cast iron, preferably a refractory grade (for example a heat-resistant casting steel such as GX40CrSi13 in which the chemical composition comprises, the contents being expressed as weight percentages : 0,3% ≤ C ≤ 0,5%, 1% ≤ Si ≤ 2,5%, 12 ≤ Cr ≤ 14%, Mn ≤ 1%, Ni ≤ 1%, P ≤ 0,04%, S ≤ 0,03% and Mo ≤ 0,5%) or a wear-resistant steel able to work at high temperatures.. The wear resistant ceramic may be, for instance, an silicon carbide (SiC), extruded silicon carbide (higher thermal conductivity) or other refractory material with good resistance to spalling and high hardness.

[0021] For instance and as illustrated in figures 1 to 4, a multilayer protrusion 10 may comprise a first layer 11 made of a material having a high thermal conductivity, and a second layer 12 made of the wear resistant material and set on top of this first layer 11. This embodiment allows an adaptation of a conventional cooling plate without any machining phase.

[0022] The first layer 11 having a high thermal conductivity is laid in the lowest position of the multilayer protrusion 10 to act as a heat shield, because the thermal load is coming mainly from hot gas streams flowing upwards. For instance, the material of this first layer 11 may be a high conductivity metal copper or a copper alloy. The second layer 12 is made of the wear resistant material and laid on top of the first layer 11 to protect it from an early erosion. As mentioned before, this second layer 12 can be made of a wear resistant steel, cast iron or ceramic.

[0023] Also for instance, and as illustrated in figures 1 to 3, each multilayer protrusion 10 may be associated to a single groove 5. In other word a part of each multilayer protrusion 10 is located into a single groove 5 while the remaining part of this multilayer protrusion 10 extends beyond this single groove 5.

[0024] In this case, each multilayer protrusion 10 may further comprise a third layer 13 sandwiched between the first 11 and second 12 layers and made of a ceramic material having a very high hardness, intended for increasing the wear resistance of the whole protrusion.

[0025] In the examples of figures 1 and 2 each third layer 13 is in contact with a part of the inner face 3 that delimitates the base of its associated groove 5, while in the example of figure **3** each third layer 13 is separated by a protruding part of the underlying first layer 11 from the part of the inner face 3 that delimitates the base of its associated groove 5. The alternative shown in Figures 1 and 2 can be installed on the stave from the front side, while the alternative displayed in Figure 3 can only be installed sideways inside the groove. The advantage of this latter variant is the higher stability of the set in case the brittle ceramic piece would be broken in pieces.

[0026] For instance, each third layer 13 may be made of a high-hardness ceramic such as SiC or extruded SiC. A ceramic can be used here because it is sandwiched and therefore protected from impact of falling material and independent of the cooling plate bending that can be induced by a thermal expansion.

[0027] In a variant of embodiment, illustrated in figure 4, the first 11 and second 12 layers of each multilayer protrusion 10 may be respectively associated to two neighboring grooves 5. In other words, a part of the first layer 11 of a multilayer protrusion 10 is located into a first groove 5, while the remaining part of this first layer 11 extends beyond this first groove 5, and a part of the second layer 12 of this multilayer protrusion 10 is located into a second groove 5 located near the first groove 5, while the remaining part of this second layer 12 extends beyond this second groove 5. So, the first layer 11 in the lower part takes the heat load towards the copper body 2, while the second layer 12 on top protects the associated first layer 11 from wear.

[0028] In this case, and as illustrated in the non-limiting example of figure 4, the first layer 11 of each multilayer protrusion 10 may comprise a slot 17 extending between the second extremities 7 and comprising an insert 18. This insert 18, embedded in a first layer 11, is made of a material having a hardness intended for increasing hardness of this first layer 11. For instance, and as illustrated in the non-limiting example of figure 4, the face of the first layer 11, in which the slot 17 is defined (or machined), may be inclined to send the gas outwards and also to help the burden flow smoothly into the « pockets » that are built with the protrusions 10.

[0029] Also for instance, and as illustrated in figure 4, each slot 17, and therefore the associated insert 18, may have a dovetail cross-section. Also for instance, each insert 18 may be made of a ceramic such as SiC or a steel (wear-resistant, heat-resistant or a combination of both). Other implementations to increase the hardness of the layer 11 can be used. For exemple, each slot 17 may be a threaded hole in which a bolt, defining an insert 18, is screwed

[0030] It is important to note that the grooves 5 in which the multilayer protrusions 10 are located may depend on the shape and/or dimensions of the blast furnace. For instance, in the example illustrated in figures 2 and 3 a multilayer protrusion 10 may be located every three grooves 5. But, in other examples a multilayer protrusion 10 may be located every two or four or even five grooves 5.

CLAIMS

1. Cooling plate for a blast furnace, said cooling plate comprising a copper body having an inner face comprising ribs parallel therebetween, having first extremities opposite therebetween and separated by grooves having second extremities opposite therebetween, wherein at least one of said grooves comprises at least a part of a multilayer protrusion extending between said second extremities and comprising at least one layer made of a wear resistant material that increases locally the wear resistance of neighboring ribs.

2. Cooling plate according to claim 1, wherein said wear resistant material is chosen from a group consisting of a metal and a ceramic.

3. Cooling plate according to claim 2, wherein said wear resistant metal is a wear-resistant steel or cast iron.

4. Cooling plate according to claim 2, wherein said wear resistant ceramic is silicon carbide, an extruded silicon carbide or other refractory material with good resistance to spalling and high hardness.

5. Cooling plate according to any one of claims 1 to 4, wherein said multilayer protrusion comprises a first layer made of a material having a high thermal conductivity, and a second layer made of said wear resistant material and set on top of said first layer.

6. Cooling plate according to claim 5, wherein said material of said first layer is chosen from a group consisting of a high conductivity metal copper and a copper alloy.

7. Cooling plate according to claim 5 or 6, wherein each multilayer protrusion is associated to a single groove.

Date Reçue/Date Received 2020-12-03

8. Cooling plate according to claim 7, wherein each multilayer protrusion further comprises a third layer sandwiched between said first and second layers and made of a ceramic with good resistance to spalling and high hardness.

9. Cooling plate according to claim 8, wherein said third layer is made of SiC or extruded SiC.

10. Cooling plate according to claim 5 or 6, wherein the first and second layers of each multilayer protrusion are respectively associated to two neighboring grooves.

11. Cooling plate according to claim 10, wherein said first layer of each multilayer protrusion comprises a slot extending between said second extremities and comprising an insert made of a ceramic or of a wear-resistant and/or heat-resistant steel.

12. Cooling plate according to any one of claims 1 to 11, wherein said inner face of said copper body comprises ribs having at least two different heights.

13. Cooling plate according to any one of claims 1 to 12, wherein said grooves have a dovetail cross-section.

14. Blast furnace, said blast furnace comprising at least one cooling plate according to any one of claims 1 to 13.

Date Reçue/Date Received 2020-12-03

1/2

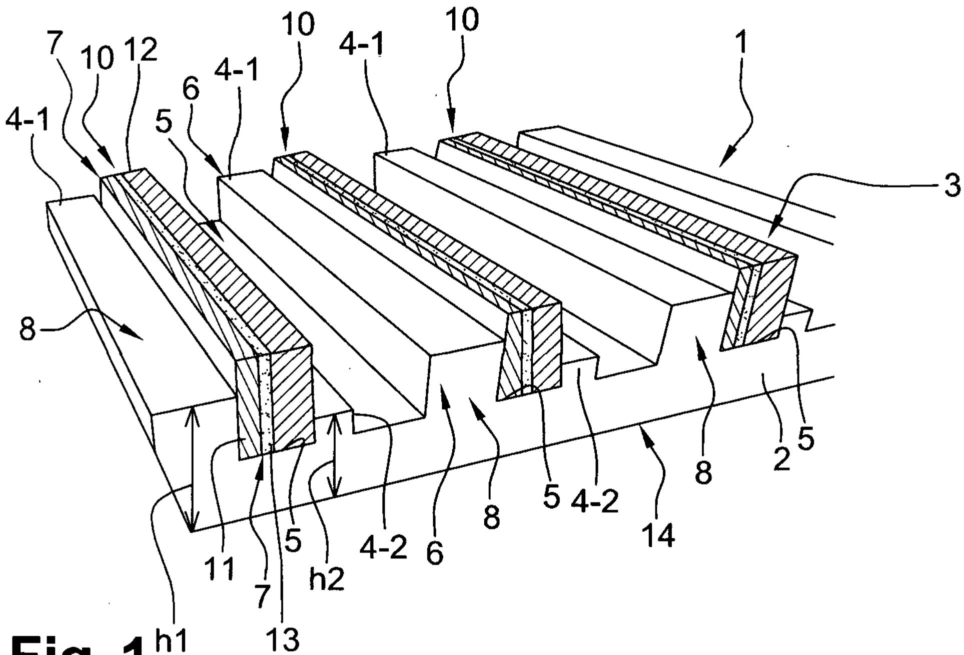


Fig. 1

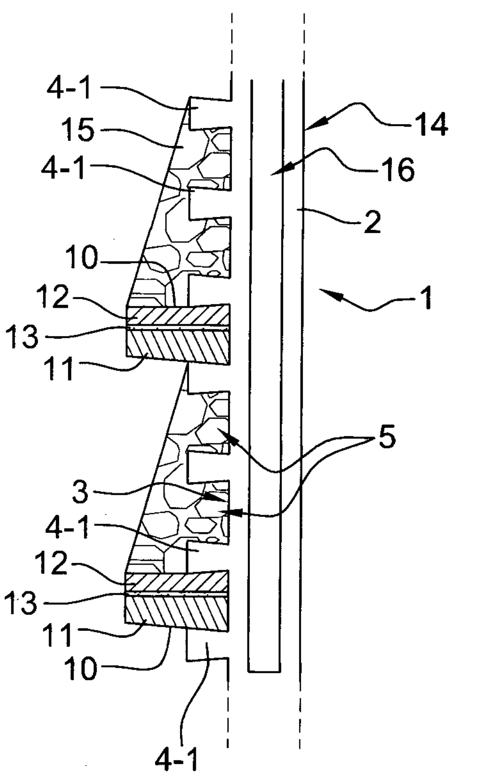


Fig. 2

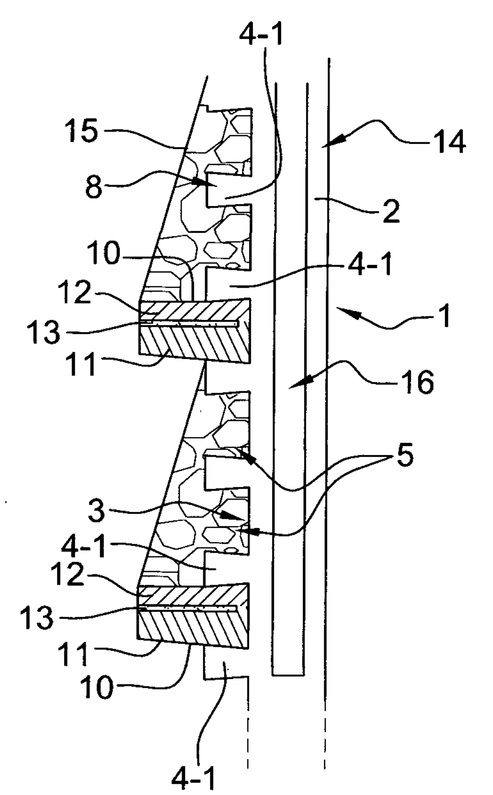


Fig. 3

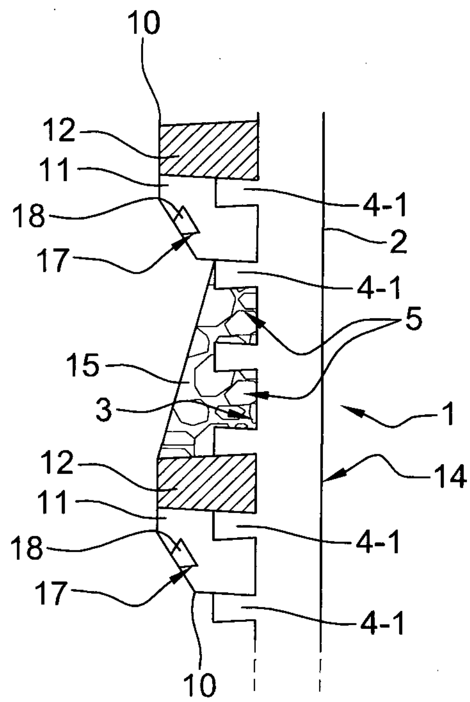
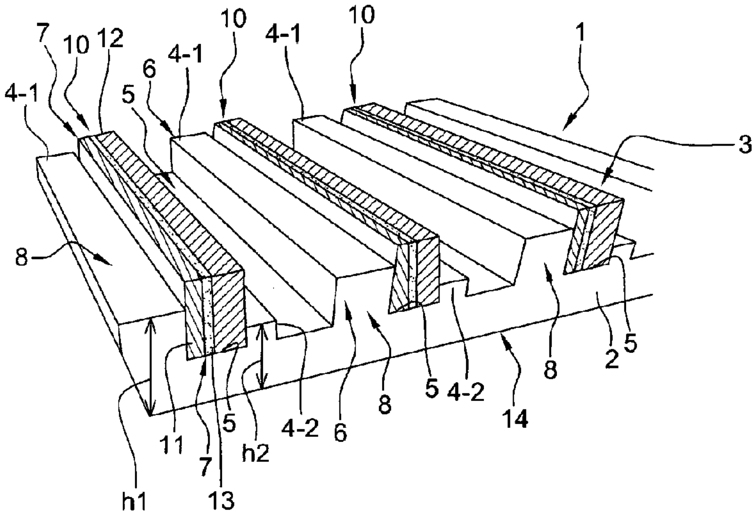


Fig. 4



7
10
12
10
4-1
10
1
4-1
6
4-1
5
10
3
8
2
5
8
5
4-2
8
5
14
8
11
5
4-2
6
7
h2
h1
13