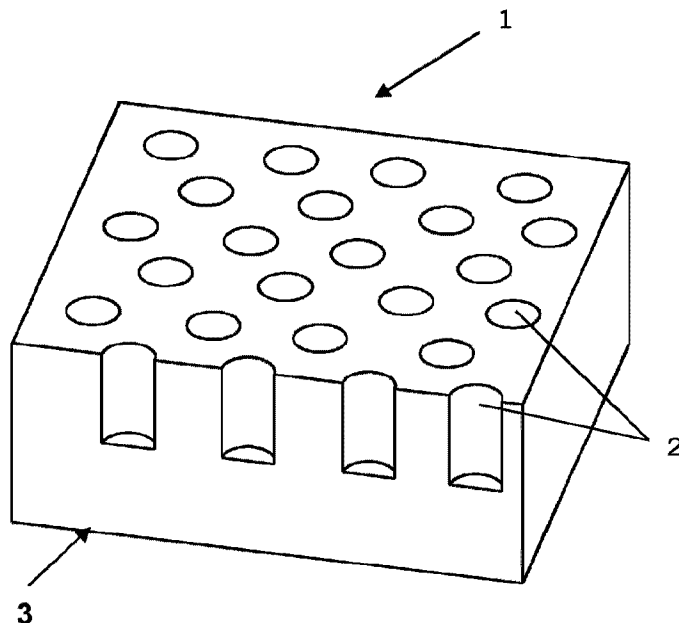




(86) Date de dépôt PCT/PCT Filing Date: 2021/01/19
(87) Date publication PCT/PCT Publication Date: 2021/08/19
(45) Date de délivrance/Issue Date: 2023/12/05
(85) Entrée phase nationale/National Entry: 2022/01/06
(86) N° demande PCT/PCT Application No.: EP 2021/051040
(87) N° publication PCT/PCT Publication No.: 2021/160381
(30) Priorité/Priority: 2020/02/11 (BE BE2020/5083)

(51) Cl.Int./Int.Cl. *B22D 19/14* (2006.01)
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(54) Titre : PIECE D'USURE COMPOSITE
(54) Title: COMPOSITE WEAR PART



(57) Abrégé/Abstract:

The present invention relates to a composite wear part comprising a ferrous alloy matrix and at least one ceramic reinforcement in the form of an insert with an open-work structure, the open-work structure comprising blind holes, the blind side of the holes being positioned on the most stressed side of said wear part.

Abstract

The present invention relates to a composite wear part comprising a ferrous alloy matrix and at least one ceramic reinforcement in the form of an insert with an open-work structure, the open-work structure comprising blind holes, the blind side of the holes being positioned on the most stressed side of said wear part.

COMPOSITE WEAR PART**Object of the invention**

[0001] The present invention relates to a composite wear part
5 made by foundry casting of a ferrous alloy. More particularly,
it relates to a wear part reinforced by a three-dimensional
ceramic recessed structure integrated into the wear part and a
geometric structure adapted to wear stress. It also discloses a
method of manufacturing said wear part.

10

State of the art

[0002] Composite wear parts made by foundry casting are well
known in the prior art. These are mainly cast iron parts
reinforced selectively on the faces most exposed to wear by
15 ceramics of the alumina-zirconia type or by carbides, nitrides
or other intermetallic elements arranged according to specific
three-dimensional geometries within the metal matrix.

[0003] The particular arrangement of the reinforcement
structures makes it possible to create hierarchical composites
20 with differentiated reinforcements according to the arrangement
or geometric shape of the reinforcement particles or structures.
In this way, it is possible to make ceramic wafers in the form
of hollow honeycomb-type structures or millimetric granule
aggregates arranged as "padding" inside a sand mold on the most
25 stressed side of the part, with interstices allowing
infiltration by the molten iron during the casting process.

[0004] There are two main types of composite parts made in
foundries where the ceramic is positioned according to a specific
three-dimensional geometry in a mold before the casting of the
30 iron, one in which the ceramic is formed before the casting and
one in which the ceramic is formed during the casting by a self-
propagating thermal reaction from reagents present in the mold.

[0005] Thus, a composite wear part can, on the one hand, be
reinforced with, for example, titanium carbide that has already

been formed, which can be placed in the mold before casting and whose interstices are simply infiltrated by the casting metal at around 1500°C, and, on the other hand, be reinforced with titanium carbide which will be formed *in situ* from the titanium and carbon reagents previously mixed in powder form and forming TiC by a self-propagating thermal reaction at around 2500°C, the reaction being initiated by the casting metal, which will then be drawn by capillary action into the reinforcing ceramic structure to fill the interstices.

10 [0006] Document WO98/15373 discloses a composite wear part with an alumina-zirconia based ceramic reinforcement in a honeycomb shape.

[0007] Document WO03/047791 discloses a composite wear part with carbide, nitride, oxide ceramics or intermetallic elements
15 formed *in situ* according to a self-propagating thermal reaction initiated by the molten cast iron which then infiltrates said ceramic structure once formed.

[0008] Documents WO2010/031660; WO2010/031661; WO2010/031663; WO 2010/031662 disclose hierarchical composite
20 wear parts reinforced with titanium carbide formed *in situ* where the reactants are introduced as granules into the mold. The wear parts are illustrated as dredge teeth, cones and crushing hammers.

[0009] Document WO2018/069006 discloses a grinding roller
25 where the wear areas are differentially reinforced depending on the wear stress.

Aims of the invention

[0010] The aim of the present invention is to provide a
30 composite wear part with a ceramic reinforcement insert having an improved geometry, where both structure and positioning are adapted to the wear stress. It is intended to re-create a resistant structure after initial wear of the ceramic reinforcement on the most stressed side of the wear part.

Summary of the invention

[0011] The present invention discloses a composite wear part comprising a ferrous alloy matrix and at least one ceramic reinforcement in the form of an insert with an openwork structure, the openwork structure comprising blind holes, the blind side of the holes being positioned on the most stressed side of said wear part.

[0012] The preferred embodiments of the invention include at least one, or any suitable combination of the following features:
-said ceramic insert comprises at least two areas (A, B), the more stressed area (A) comprising a majority of blind holes and the less stressed area (B) comprising a majority of through holes,

- the section of the holes of the ceramic insert in the area (A) is smaller than the section in the area (B) of said wear part,
- the total section of the openings in the insert on side (A) is smaller than the total section of the openings on side (B),

- the blind side of the ceramic insert is partially or entirely formed by a ceramic which has a different composition than that forming the area (B) with the through holes,

- the insert comprises at least two superimposed ceramic reinforcement structures (D, E) in the area (A),

- the blind holes are arranged obliquely in the insert.

- the blind holes have a frustoconical shape,

- the ceramic insert comprises alumina-zirconia,

- the ceramic insert comprises carbides formed *in situ* by a self-propagating exothermic reaction, preferably titanium carbide,

- the ceramic insert comprises grains of a ceramic-metal composite (CERMET),

- the ceramic structure comprises alumina-zirconia in proportions of alumina ranging from 10 to 90% by volume and zirconia ranging from 90 to 10% by volume, zirconia being optionally stabilized with yttria.

[0013] The present invention also discloses a method for producing a wear part according to the invention comprising the following steps:

- providing a mold for making a wear part by casting a ferrous alloy,
- placing an insert according to the invention in the form of a an aggregate of millimetric granules of ceramic material or infiltrable ceramic material precursors in the mold with the blind side on the most stressed side of the wear part,
- infiltration of the insert by the molten ferrous alloy.

[0014] The method according to the invention is preferably implemented with:

- a ferrous alloy comprising steel or cast iron,
- millimetric ceramic granule aggregates or infiltrable ceramic precursor aggregates are selected from the following compositions:
 - o Alumina-zirconia in proportions of 90/10 to 10/90, zirconia being optionally stabilized with yttria,
 - o Carbon and titanium powder optionally comprising iron powder as a moderator of the reaction initiated by the casting of the ferrous alloy,
 - o Ceramic-metal composites (CERMET).

[0014a] According to an embodiment, there is provided a composite wear part comprising: a ferrous alloy matrix and at least one ceramic reinforcement insert having an openwork structure, the openwork structure of the ceramic reinforcement insert comprising blind holes: wherein blind ends of the blind holes are positioned on a side of the composite wear part most exposed to wear; wherein the ceramic reinforcement insert comprises at least two adjacent areas having openings, wherein the openings comprise the blind holes and through holes, and wherein the at least two adjacent areas comprise a first area, and a second area, wherein the first

area is configured to experience more stress than the second area, and wherein the first area comprises a majority of the blind holes, and wherein the second area comprises a majority of the through holes.

[0014b] According to another embodiment, there is provided a method for making a wear part comprising a ferrous alloy matrix and at least one ceramic reinforcement insert having an openwork structure, the openwork structure comprising blind holes, the method comprising the following steps: providing a mold for making the wear part by casting a ferrous alloy; placing the insert in the form of an aggregate of millimetric granules of ceramic material or infiltrable ceramic material precursors in the mold, with a blind side of the ceramic reinforcement insert on the side of the wear part most exposed to wear; and causing an infiltration of the insert by molten ferrous alloy.

[0014c] According to another embodiment, there is provided a composite wear part, comprising: a ferrous alloy matrix and at least one ceramic reinforcement insert having an openwork structure, the openwork structure comprising a plurality of blind holes; wherein the blind holes are oriented such that closed bottoms of the blind holes are toward a face of the composite wear part most exposed to wear; wherein the ceramic reinforcement insert comprises at least two adjacent zones having openings, wherein the openings comprise the plurality of blind holes and a plurality of through holes: a first zone comprising a majority of the blind holes, and a second zone comprising a majority of the through holes; and wherein the first zone is configured to provide higher resistance to wear than the second zone.

Brief description of the figures

[0015] In the figures discussed below, "inserts" are defined as infiltrable three-dimensional structures formed of more or less porous aggregates or agglomerates of millimeter-sized particles with interstices.

[0016] For ease of representation, the figures illustrate only the three-dimensional outline of these inserts placed in the reinforced portions of the wear part.

[0017] Figure 1 represents the element of a ceramic insert with blind holes according to the invention. The insert is here schematically shown in its simplest form. Such an insert is

positioned with the blind side on the face most exposed to wear. Such an insert has numerous interstices, or pores (not illustrated) which are intended to be infiltrated by the ferrous alloy during casting.

5 [0018] Figure 2 represents a ceramic insert based on the same principle as that described in Figure 1, but with larger blind holes illustrating the different possibilities of making blind holes in such a ceramic insert.

[0019] Figure 3 represents a ceramic insert with blind holes
10 based on the same principle as that described in Figure 1, but this time the insert has two different ceramic layers D and E.

[0020] Figure 4 represents a ceramic insert with blind holes based on the same principle as that described in Figure 3, but this time with deeper blind holes penetrating into the second
15 layer E.

[0021] Figure 5 represents a ceramic insert with blind holes based on the same principle as that described in Figure 3, but this time made with enlarged holes.

[0022] Figure 6 represents a ceramic insert with blind holes
20 based on the same principle as that described in Figure 1, but this time with blind holes combined in approximately equal proportions with through holes of larger section.

[0023] Figure 7 represents a ceramic insert with blind holes based on the same principle as that described in Figure 1, but
25 this time with blind holes combined in a minor proportion with through holes of larger section. Here the blind holes, which have a smaller diameter than the through holes, are in the majority.

[0024] Figure 8 represents a ceramic insert with two different
30 stress areas A and B. Area A, which is more exposed to wear, comprises mainly blind holes, and area B, which is less exposed to wear, comprises mainly through holes. The through holes in area B have a larger section than the blind holes.

[0025] Figure 9 represents the same configuration as Figure 8, but this time with a different ceramic on side A and side B.

[0026] Figure 10 represents the same configuration as Figure 8, but this time not only with a different ceramic on side A and side B, but also with two different ceramic layers D and E in area A, with a more wear-resistant ceramic on the blind side of area A.

[0027] Figure 11 represents a ceramic insert according to the invention with obliquely positioned blind holes.

10 [0028] Figure 12 represents a ceramic insert according to the invention with blind holes in a frustoconical shape.

[0029] Figure 13 represents an illustrative example of a wear part according to the invention in the form of a grinding roller for a vertical rotary grinder where the area A most exposed to wear comprises the ceramic insert with blind holes. Area A is adjacent to a less wear-exposed area B comprising through holes.

[0030] Figure 14 schematically represents the use of a grinding roller on a table of a vertical rotary grinder.

[0031] Figure 15 schematically represents a grinding cone with a ceramic insert with blind holes.

List of reference symbols

- 1: Ceramic insert
- 2: Blind holes
- 25 3: Most stressed face of the wear part
- 4: Through holes
- 5: Grinding roller
- 6: Schematic representation of a vertical rotary grinder with grinding roller and grinding table
- 30 A: Most stressed area of the wear part
- B: Least stressed area of the wear part
- D: Upper layer of the ceramic insert
- E: Lower layer of the ceramic insert oriented towards the side most exposed to wear

Detailed description of the invention

[0032] Wear parts cast in foundries are very common in the mining industry for grinding rocks and ores or in the field of dredging. Without being restrictive, we can for example mention,
5 in the case of rock grinding, composite impactors for impact crushers, mobile cones for compression crushers or roller tables for vertical compression grinders.

[0033] The stresses with which the wear parts in these machines are confronted are both impact resistance and wear
10 resistance. For this reason, the hardness of a ceramic material (carbides, nitrides, oxides of various types, etc.), which is wear resistant but not impact resistant, is usually combined with a ferrous alloy such as cast iron or steel, which provides a certain level of ductility to resist impact but is less wear
15 resistant.

[0034] Combining these two types of material is not easy, however, because they have very different coefficients of expansion which can generate micro-cracks when the parts are cooled and which, because of these potential defects, cancel out
20 this synergy effect in a composite wear part.

[0035] An additional difficulty lies in the problem of the complete infiltration of the ceramic insert by the molten cast iron which tends to cool in contact with it, thus preventing satisfactory infiltration (except for the reactions of *in situ*
25 ceramic formation by self-propagating exothermic reaction).

[0036] Many configurations of ceramic inserts have been tested by the industry. The most popular insert is a relatively easy-to-infiltrate "honeycomb" shape where areas of high ceramic concentration alternate with areas of low ceramic concentration.

30 [0037] Ceramic reinforcements are typically introduced as a prefabricated ceramic insert or even as an insert in which the interstices have already been filled with molten cast iron and cooled before being re-introduced into a mold to cast the desired wear part.

[0038] There is a great deal of know-how involved in the production of a ceramic insert, as it must have a porous structure to be infiltrated by the molten cast iron, the level of porosity being decisive, which has led to a whole series of technologies for the manufacture of powder agglomerates (aggregates) in the form of clogged grains of a few millimeters in diameter, which are then assembled into a "padding" structure with more or less large interstices, depending in particular on the thickness of the insert to be infiltrated and its position in the mold.

[0039] There are many compositional possibilities for producing an insert according to the invention. In a non-exhaustive list, we can mention:

- alumina-zirconia 10/90 to 90/10 with or without stabilization in the form of millimetric granules assembled into aggregates in an infiltrable structure.
- particles from ground CERMET based on carbides, nitrides, borides or intermetallic elements for example, then agglomerated in an infiltrable porous structure.
- ceramics formed by self-propagating exothermic synthesis (SHS) such as titanium carbide from carbon and titanium powders, possibly mixed with a powder to moderate the reaction such as iron powder which can be present in the form of agglomerated millimetric grains with interstices. The reaction between the carbon and the titanium is initiated by the casting of the ferrous alloy.
- etc.

[0040] Holding the insert in the mold during casting also requires a certain know-how acquired by the industry over the years.

[0041] The configuration and positioning of ceramic inserts within a composite wear part has been the subject of much research, all of which has led to the observation that the wear rate results obtained during the tests are relatively

unpredictable because they depend on the specific application, i.e., the type of machine used and the type of rock to be ground, or the intermittence of use.

[0042] The situation is made even more complex by the fact
5 that during the wear phenomenon, the geometry of the wear part changes and the areas that are not very stressed at the beginning become much more so as wear progresses. Thus, a compromise regarding the structure of the insert is often required to reconcile short- and long-term wear, both of which can vary
10 considerably from case to case.

[0043] The inventors of the present invention have now produced a ceramic insert structure that perfectly reaches this compromise. This includes an openwork structure with blind holes, the blind side being placed on the most stressed side of
15 the wear part so as to provide high resistance to wear in the beginning of use and, once the blind side (bottom of the holes) has been worn away, resistance to impact and wear owing to through holes.

[0044] The holes made in the structure of the insert have a
20 diameter generally between 1 and 10 cm, preferably between 1 and 8 cm and more preferably between 1 and 4 cm.

[0045] The depth of the blind holes depends on the total thickness of the insert and the specific use, and generally represents between 20 and 85% of the total thickness, preferably
25 between 30 and 80% and more preferably between 40 and 70%.

[0046] The insert can be made in several superimposed layers (D and E) or with adjacent parts (A and B). Thus, the blind side may be made of a ceramic that has a different composition than the one including the holes superimposed on it or adjacent to it
30 (see figures).

[0047] Although a round cross-section is preferred for the holes, it is clear that the invention is not limited to this shape. Thus, the holes may have any cross-sectional shape, such as hexagonal squares or any shape.

[0048] A partially recessed insert with blind holes can also be contemplated where blind holes are next to through holes, the proportion of blind holes by area should however be significant, i.e., greater than 20%, preferably greater than 40% and more preferably greater than 60%.

[0049] When the insert is formed of two adjacent areas, one comprising mainly blind holes and the other comprising mainly through holes, the blind holes in the most stressed area of the wear part have a smaller section and/or opening surface than the holes in the less stressed area.

[0050] The general concept of the invention lies in the fact that the first wear occurs on a side reinforced by an insert which is mainly free of holes, in this case the blind side of the insert, which, once worn, still offers a high resistance to wear with through holes having a section which is smaller than the sections of the through holes on the less stressed side of the wear part.

[0051] Although the invention is not limited to a specific ceramic composition, ceramics based on alumina-zirconia or titanium carbide, placed as is in the mold (cermet grains) or formed *in situ* by the self-propagating thermal reaction are preferred. Alumina-zirconia proportions comprising 10-90% alumina and 90-10% zirconia by volume are preferred, zirconia being optionally stabilized with yttria.

[0052] **Examples**

The present invention has been illustrated by a roller of a vertical rotary grinder and moving parts of a cone crusher which have been made with, on the one hand, an insert including through holes according to the prior art and, on the other hand, with inserts including essentially blind holes according to the invention.

The wear rate was compared under the following conditions:

Machine type: Secondary cone crusher

Type of wear part: Moving part

Type of ground material: Rhyolite 50-150 mm

- 5 Number of operating hours with and without through-hole inserts on the most stressed part:

Cone crusher	Service life	Superiority factor (SF)
Through-hole inserts	220 H	1
Blind hole inserts	308 H	1.4

Type of machine: Vertical grinder

Type of wearing part: Roller

- 10 **Type of ground material:** Silico-lime

Number of operating hours with and without through-hole inserts on the most stressed part:

Vertical grinder	Wear rate	Superiority factor (SF)
Through-hole inserts	32 mm/kh	1
Blind hole inserts	21 mm/kh	1.5

CLAIMS:

1. A composite wear part comprising:

a ferrous alloy matrix and at least one ceramic reinforcement insert having an openwork structure, the openwork structure of the ceramic reinforcement insert comprising blind holes:

wherein blind ends of the blind holes are positioned on a side of the composite wear part most exposed to wear;

wherein the ceramic reinforcement insert comprises at least two adjacent areas having openings, wherein the openings comprise the blind holes and through holes, and wherein the at least two adjacent areas comprise a first area, and a second area, wherein the first area is configured to experience more stress than the second area, and wherein the first area comprises a majority of the blind holes, and wherein the second area comprises a majority of the through holes.

2. The composite wear part of claim 1, wherein a cross-sectional area of each of the blind holes of the ceramic reinforcement insert in the first area is smaller than a cross-sectional area of each of the through holes in the second area of the composite wear part.

3. The composite wear part of claim 1, wherein a total cross-sectional area of the openings in the ceramic reinforcement insert in the first area is smaller than a total section of the openings in the second area.

4. The composite wear part of claim 1, wherein a side of the ceramic reinforcement insert comprising the blind ends of the blind holes is at least partially formed by a ceramic having a different composition than a ceramic forming the second area.

5. The composite wear part of claim 1, wherein the first area further comprises a second ceramic reinforcement structure superimposed onto the at least one ceramic reinforcement insert.

6. The composite wear part of claim 1, wherein the blind holes are obliquely arranged in the ceramic reinforcement insert.

7. The composite wear part of claim 1, wherein the blind holes have a frustoconical shape.

8. The composite wear part of claim 1, wherein the ceramic reinforcement insert comprises alumina-zirconia.

9. The composite wear part of claim 1, wherein the ceramic reinforcement insert comprises carbides formed in situ by a self-propagating exothermic reaction.

10. The composite wear part of claim 9, wherein the carbides formed in situ comprise titanium carbide.

11. The composite wear part of claim 1, wherein the ceramic reinforcement insert comprises grains of a ceramic-metal composite (CERMET).

12. The composite wear part of claim 1, wherein the at least one ceramic openwork structure comprises alumina-zirconia in proportions of alumina ranging from 10 to 90 % by volume and zirconia ranging from 90 to 10 % by volume.

13. The composite wear part of claim 12, wherein the zirconia is stabilized yttria.

14. A method for making a wear part comprising a ferrous alloy matrix and at least one ceramic reinforcement insert having an

openwork structure, the openwork structure comprising blind holes, the method comprising the following steps:

providing a mold for making the wear part by casting a ferrous alloy;

placing the insert in the form of an aggregate of millimetric granules of ceramic material or infiltrable ceramic material precursors in the mold, with a blind side of the ceramic reinforcement insert on the side of the wear part most exposed to wear; and

causing an infiltration of the insert by molten ferrous alloy.

15. The method according to claim 14, wherein the ferrous alloy comprises steel or cast iron.

16. The method according to claim 14, wherein the millimetric ceramic granule aggregate or infiltrable ceramic precursor aggregate is selected from the following compositions:

Alumina-zirconia in proportions of 90/10 to 10/90 by volume, or

Alumina-zirconia in proportions of 90/10 to 10/90 by volume wherein the zirconia is stabilized with yttria.

17. The method according to claim 14, wherein the millimetric ceramic granule aggregate or infiltrable ceramic precursor aggregate comprises (a) carbon and titanium powder or (b) carbon and titanium powder comprising iron powder as a moderator of the reaction initiated by the casting of the ferrous alloy.

18. The method according to claim 14, wherein the millimetric ceramic granule aggregate or infiltrable ceramic precursor aggregate comprises ceramic-metal composites (CERMET).

19. A composite wear part, comprising:

a ferrous alloy matrix and at least one ceramic reinforcement insert having an openwork structure, the openwork structure comprising a plurality of blind holes;

wherein the blind holes are oriented such that closed bottoms of the blind holes are toward a face of the composite wear part most exposed to wear;

wherein the ceramic reinforcement insert comprises at least two adjacent zones having openings, wherein the openings comprise the plurality of blind holes and a plurality of through holes: a first zone comprising a majority of the blind holes, and a second zone comprising a majority of the through holes; and

wherein the first zone is configured to provide higher resistance to wear than the second zone.

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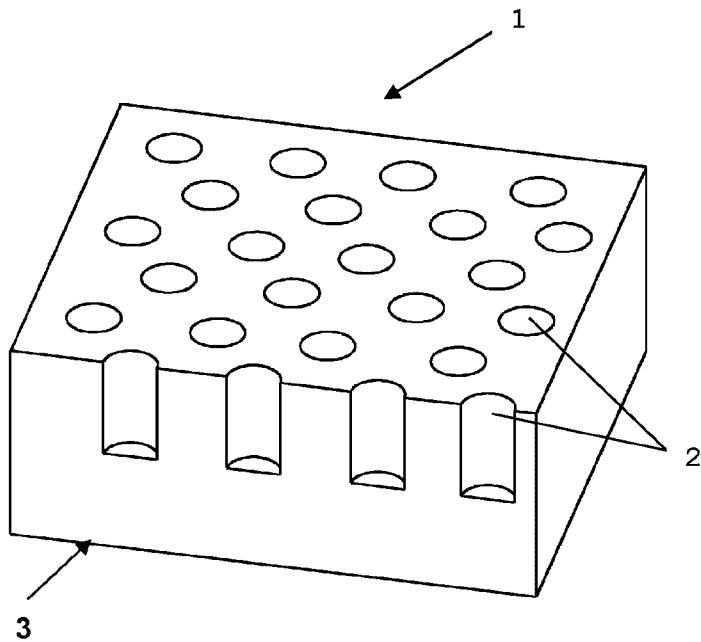


Fig.1

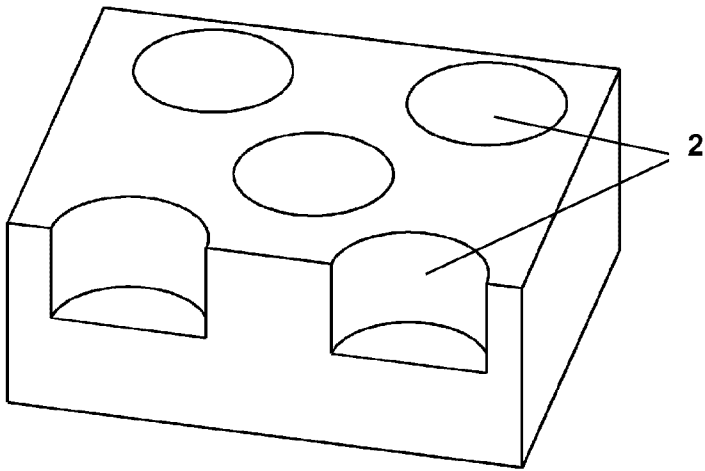


Fig.2

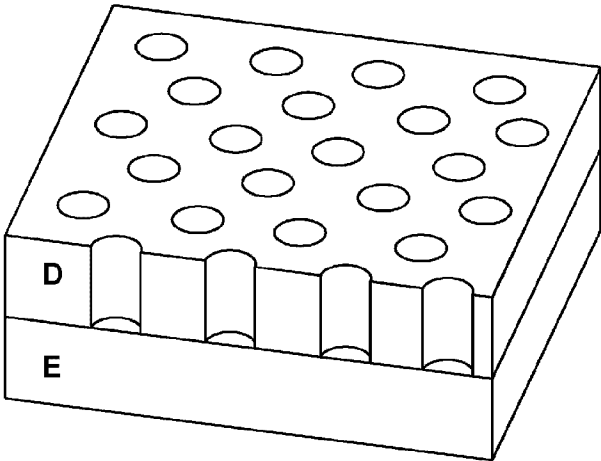


Fig.3

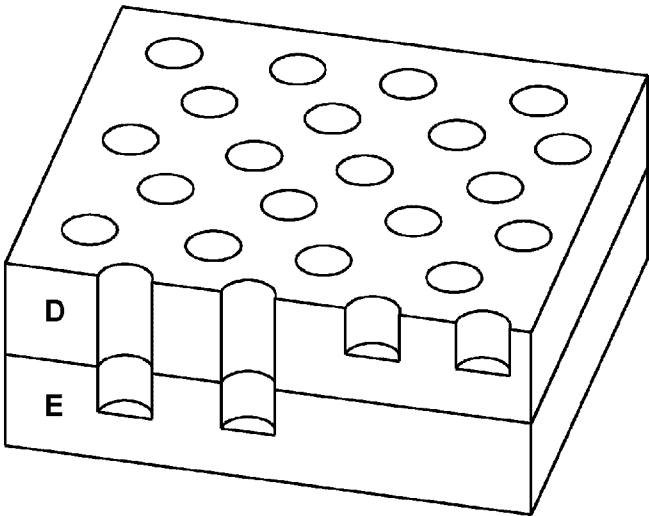


Fig.4

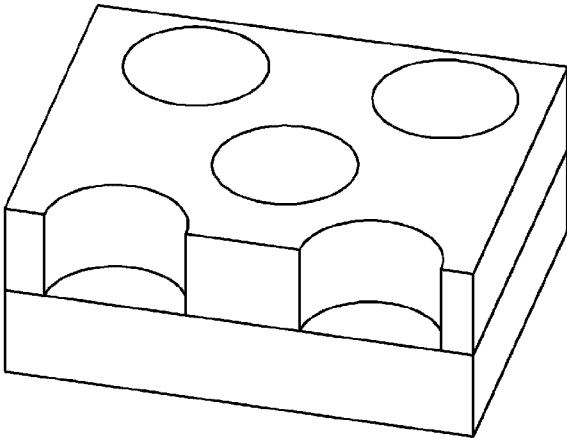


Fig.5

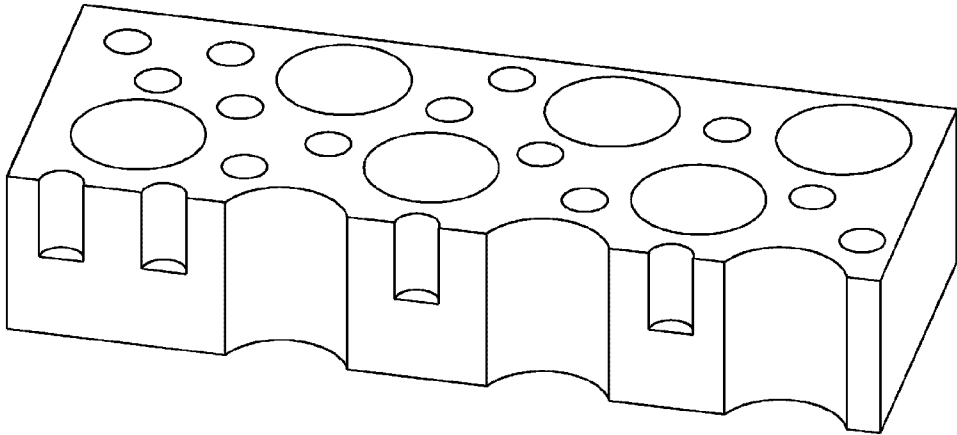


Fig.6

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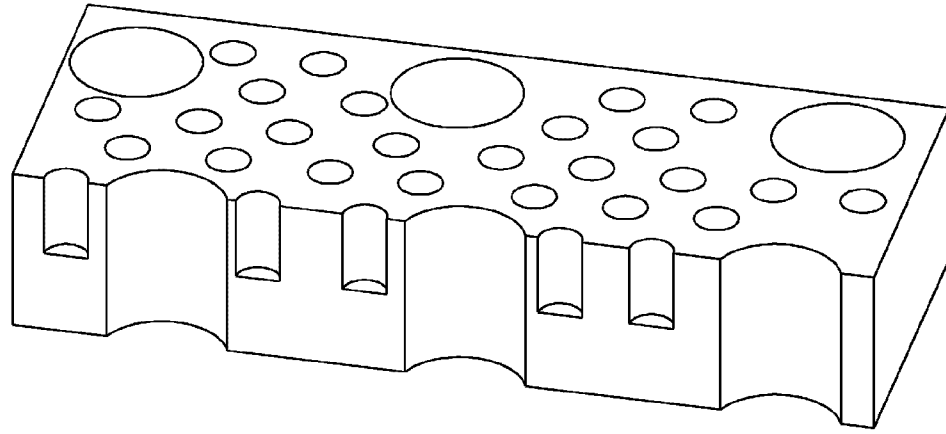


Fig.7

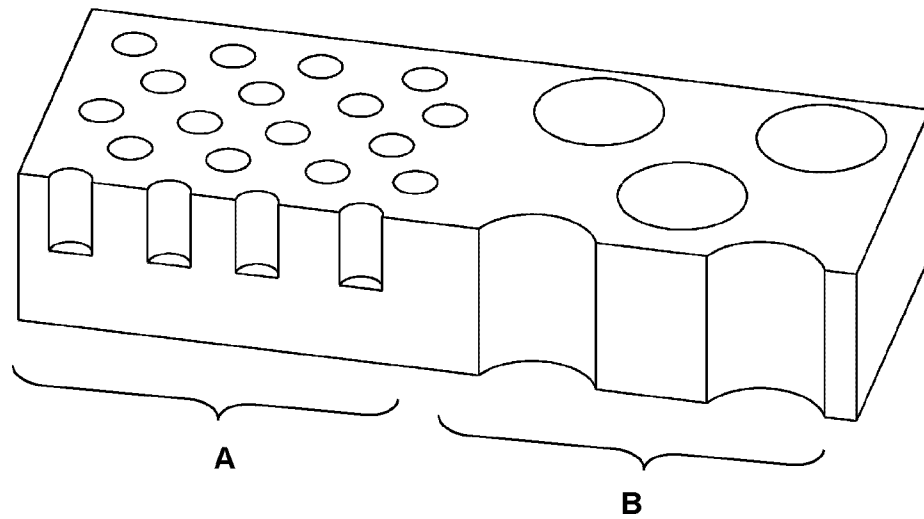


Fig.8

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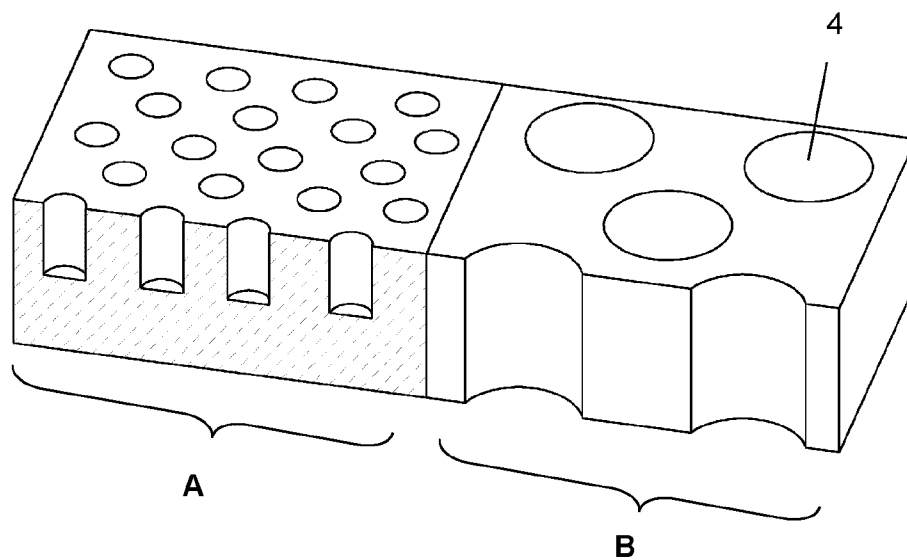


Fig.9

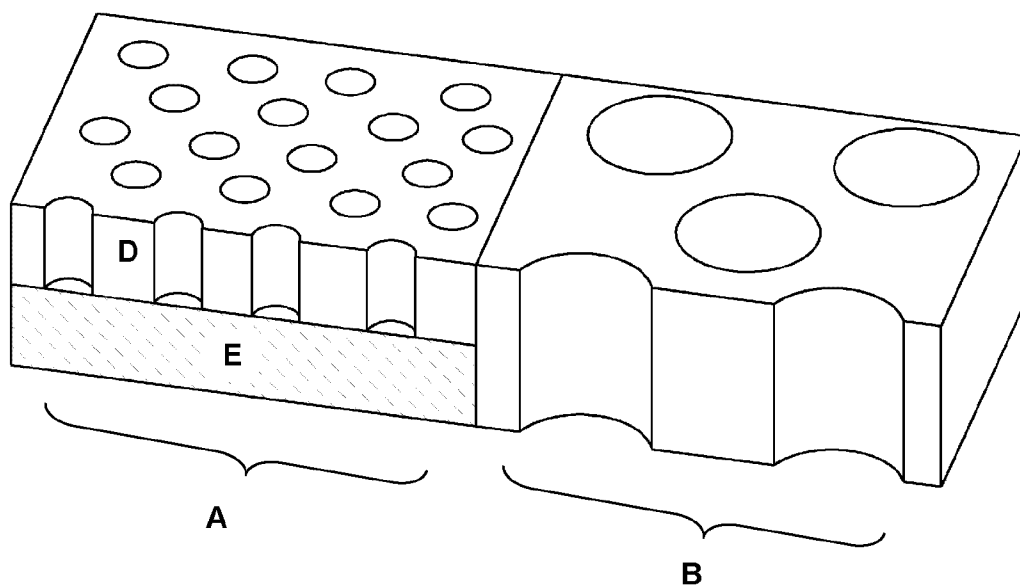


Fig.10

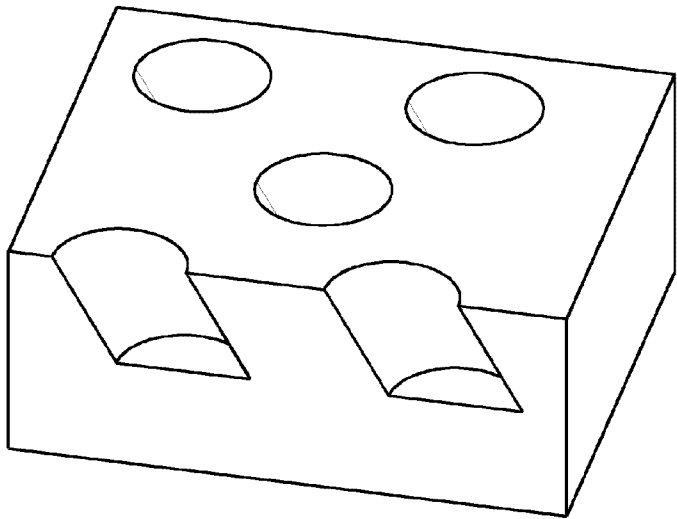


Fig.11

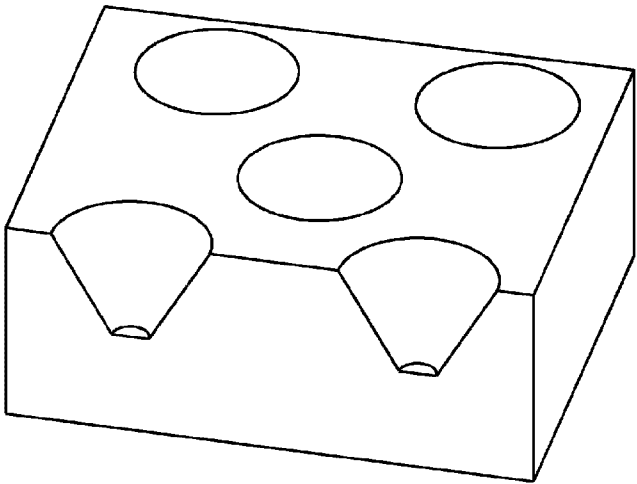


Fig.12

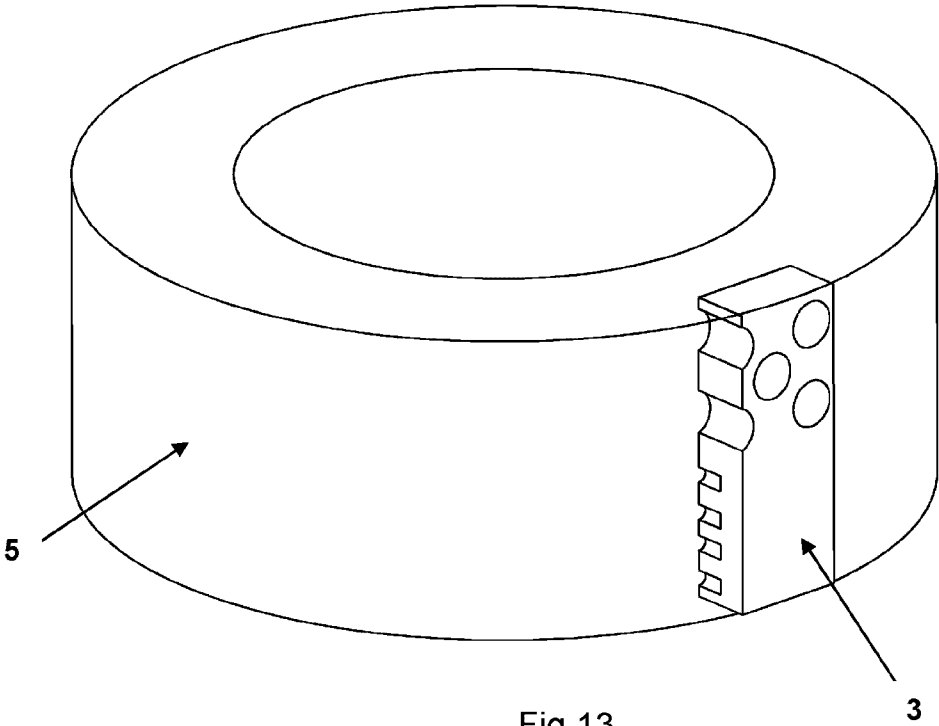


Fig.13

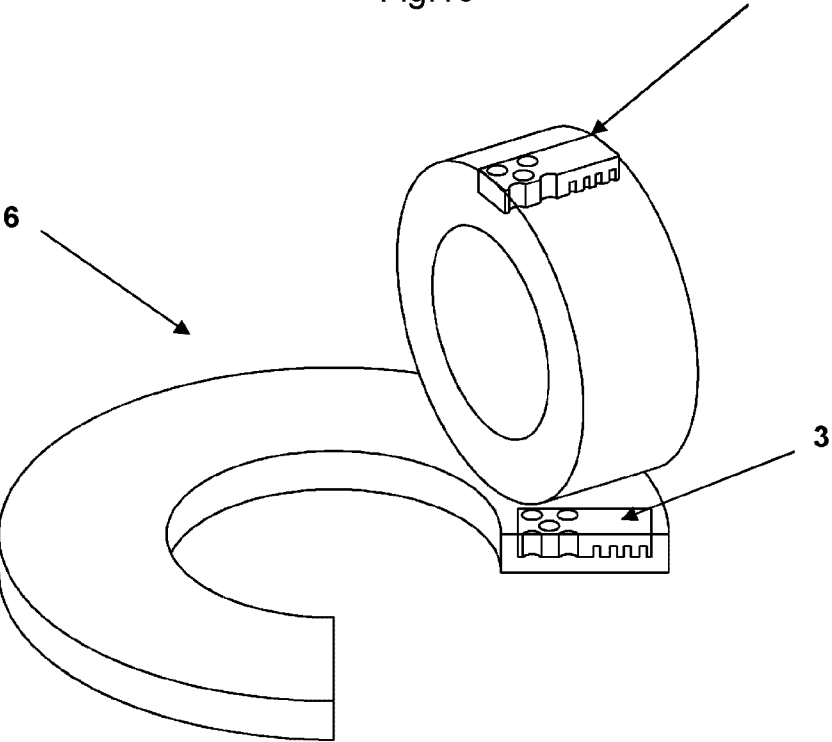


Fig.14

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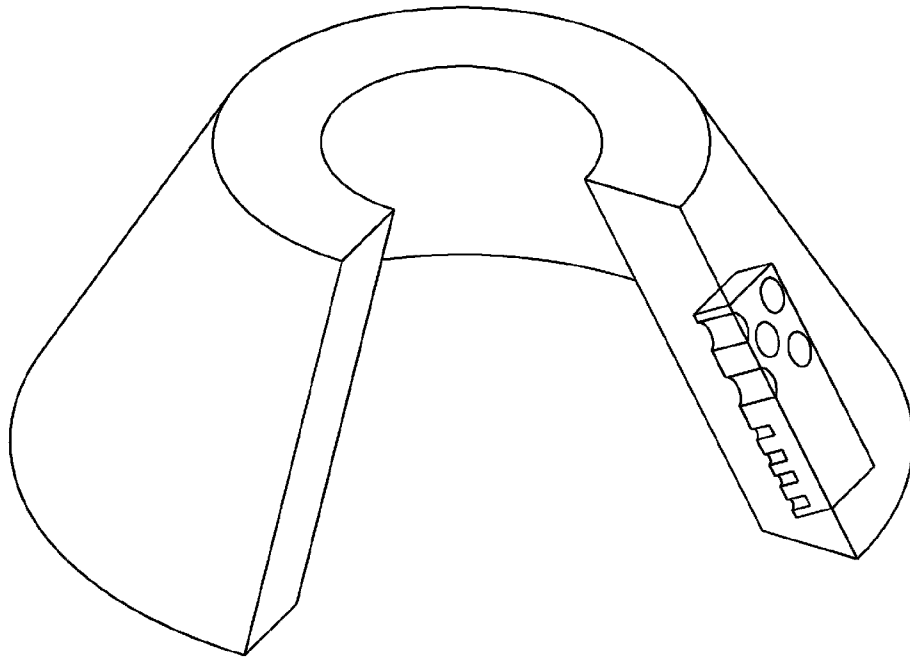


Fig.15

