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

(11) EP 3 871 807 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
01.09.2021 Bulletin 2021/35

(51) Int Cl.:
B22D 19/02 *(2006.01)* ***B22D 19/06*** *(2006.01)*
B22D 19/08 *(2006.01)*

(21) Application number: **21156550.2**

(22) Date of filing: **11.02.2021**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **24.02.2020 CN 202010112564**
16.10.2020 AU 2020256420

(71) Applicant: **Parksen Group Pty Ltd**
Bondi Junction, NSW 1355 (AU)

(72) Inventor: **Wang, Qiang**
Beijing, 100020 (CN)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) METHOD FOR DESIGNING A PREARRANGED HARD SURFACE OR HARD POINTS FOR CASTING PRODUCT AND CORRESPONDING CASTING

(57) Disclosed is a casting manufacturing method, comprising: using a scanner to obtain contour data of an unworn casting; using a scanner to obtain contour data of the casting in a state of wear limit; obtaining contour data of the worn-off portion according to the contour data of the unworn casting and the contour data of the casting in a state of wear limit; and manufacturing a hard surface or arranging hard points according to the contour data of the worn-off portion so that the overall shape of the hard surface or hard points is consistent with the contour of the worn-off portion.

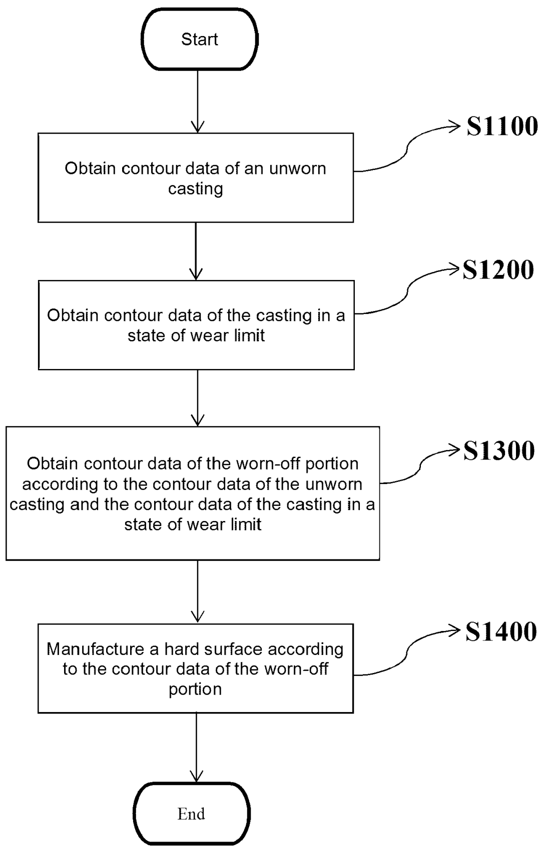


Fig. 7

EP 3 871 807 A1

Description

Related Applications

[0001] This application claims priority from Chinese Patent Application No. 202010112564.X filed on 24 Feb 2020 and Australian Patent Application No. 2020256420 filed on 16 October 2020, the content of each is herein incorporated by reference in its entirety.

Technical Field

[0002] The present invention relates to a design method of casting products, specifically to a method for designing prearranged a hard surface or hard points for cast steel product.

Background

[0003] Cast steel products, including cast alloy steel products, are widely used in industrial fields, especially in mining mechanical equipment. The manufacturing process of cast steel products is well known. First, a mold is designed and made, then steel is melted and the molten steel is poured into the mold and finally, the molten steel is processed into a finished product after cooling and shaping.

[0004] Cast steel products and mechanical products of any other material have the problem of wear during use. If the wear reaches a certain degree, the product must be scrapped and its service life will end. In order to enhance wear resistance and prolong the service life of the product, in the prior art, a surface layer made of a more wear-resistant material, i.e., a hard surface, is added to the surface of the cast steel product, or, a plurality of columns made of a more wear-resistant material are embedded on the surface of the cast steel product, that is, a plurality of hard points are embedded. The materials constituting the hard surface or hard points include, for example, Al_2O_3, tungsten carbide, titanium carbide, nickel-chromium alloy and zirconium alloy.

[0005] In the prior art, the setting of a hard surface or hard points has the following defects:

1. Too many human factors;
2. Lack accurate diagnosis and analysis formed based on the wear characteristics of castings;
3. Unable to provide an objective and error-free hard surface or hard point design scheme; and
4. Without a design scheme, the research and development of hard surface technology stays in technological update of hard surface and hard point materials, other than reasonable application of existing technologies, thereby wasting huge resources.

Summary

[0006] It is an object of the present invention to substantially overcome or at least ameliorate one or more of the above disadvantages. In some embodiments, the thickness distribution of the hard surface or the length distribution of each hard point is quantitatively determined according to the actual degree of wear of the cast steel product during use.

[0007] According to one aspect of the present disclosure, there is provided a casting manufacturing method, comprising:

obtaining contour data of an unworn casting;
obtaining contour data of the casting in a state of wear limit;
obtaining contour data of the worn-off portion according to the contour data of the unworn casting and the contour data of the casting in a state of wear limit; and
manufacturing a hard surface according to the contour data of the worn-off portion so that the manufactured hard surface and the worn-off portion have substantially the same contour.

[0008] According to another aspect of the present disclosure, a casting manufacturing method is provided, comprising: obtaining contour data of an unworn casting (the casting can be a part of an apparatus); then, obtaining contour data of the casting in a state of wear limit; obtaining contour data of the worn-off portion according to the contour data of the unworn casting and the contour data of the casting in a state of wear limit; and then, manufacturing a hard surface according to the contour of the worn-off portion.

[0009] Further, putting the manufactured hard surface into a mold and pouring molten steel or alloy into the mold so that the cooled molten steel or alloy is combined with the hard surface to form a casting with a hard surface.

[0010] In an embodiment, the material constituting the hard surface and the materials for other parts of the casting have similar mechanical properties.

[0011] In an alternative embodiment, the material constituting the hard surface is more corrosion resistant than the materials for other parts of the casting.

[0012] According to another aspect of the present disclosure, a casting manufacturing method is provided, comprising: obtaining contour data of an unworn casting; then, obtaining contour data of the casting in a state of wear limit; obtaining contour data of the worn-off portion according to the contour data of the unworn casting and the contour data of the casting in a state of wear limit; determining the maximum fusible density of molten steel and hard points and setting the actual hard point density and thickness of each hard point (e.g., cross section or diameter) to be adopted (the actual hard point density to be adopted is smaller than or equal to the maximum fusible density of molten steel and hard points); calculating the total number of hard points and the coordinates of each hard point on the horizontal plane according to the set actual hard point density to be adopted; calculating the length of each hard point (i.e., the total cross section length of numerous particles of the wear-resistant material constituting the hard point) according to the contour data of the worn-off portion and the coordinates of each hard point; manufacturing hard points with a corresponding length and required transverse section; fixing the plurality of hard points to corresponding coordinates in the mold respectively, with the length of each hard point being consistent with the thickness at the corresponding location of the contour data of the worn-off portion; and pouring molten steel or alloy into the mold so that the cooled molten steel or alloy is combined with the hard points to form a casting with hard points.

[0013] In the foregoing casting manufacturing method, those skilled in the art can understand that the step of determining the maximum fusible density of molten steel and hard points is to determine the maximum weight ratio between molten steel or alloy and hard points to keep the weight ratio between molten steel or alloy and hard points in a reasonable range, thereby ensuring that the solid composite of the molten steel or alloy and the hard points is firm, not easy to generate cracks, and ensuring that the hard points are not easy to fall off.

[0014] Further, if the length of the hard points is too large, the hard points cannot be firmly fused with the casting. That is to say, in practical applications, the length of the hard points has an upper limit, i.e., the maximum usable length of hard points. If the worn length (or depth) at some locations of the extremely worn surface exceeds the maximum usable length of hard points, the arrangement of each hard point should be reduced in proportion to the maximum usable length to ensure that the contour of wear limit is basically consistent with the contour of the original casting.

[0015] The present invention further provides a casting manufactured according to the method of the present invention and arranged with a hard surface or hard points.

Brief Description of the Drawings

[0016] Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic sectional view of an irregularly shaped casting according to an embodiment of the present invention;

Fig. 2 is a schematic sectional view of the casting shown in Fig. 1 when it reaches the limit of its service life after being worn;

Fig. 3 is a comparison diagram of the sectional contours before and after wear obtained by overlapping the sectional views in Fig. 1 and Fig. 2;

Fig. 4 is a sectional view of a hard surface manufactured according to an embodiment of the present invention;

Fig. 5 is a sectional view of a casting arranged with a hard surface according to an embodiment of the present invention;

Fig. 6 is an overlapping diagram obtained by overlapping a comparison diagram of the sectional contours of a casting not arranged with a hard surface before and after wear and a comparison diagram of the sectional contours of a casting arranged with a hard surface according to an embodiment of the present invention before and after wear;

Fig. 7 is a flow diagram of manufacturing a casting arranged with a hard surface according to an embodiment of the present invention;

Fig. 8 is a schematic sectional view of a casting arranged with a plurality of hard points according to an embodiment of the present invention;

Fig. 9 is a schematic sectional view of a casting arranged with a plurality of hard points according to an alternative embodiment of the present invention;

Fig. 10 is a flow diagram of manufacturing a casting arranged with hard points according to an embodiment of the present invention.

Detailed Description

[0017] In order to make the objects, technical solutions and advantages of the present invention more evident, the present invention is further described in detail below with reference to embodiments and accompanying drawings. It should be understood that the specific embodiments described herein are intended to illustrate and not to limit the present invention.

[0018] Fig. 1 is a sectional contour diagram of a hypothetical irregularly shaped casting 100 (the casting is, for example, a cast steel product) in an example of the present invention. The casting 100 is to be assembled into an apparatus including a plurality of parts. During use, the casting 100 and other parts of the apparatus are in contact with and wear each other, so that the upper surface 101 of the casting 100 is gradually worn. In order not to lose universality, the casting 100 in this embodiment shown in Fig. 1 has an irregular upper surface 101, but it is not a limitation and the method of the present invention can be applied to castings with various regular geometric shapes or irregular shapes.

[0019] In a method according to an embodiment of the present invention, firstly, a scanner is used to scan a casting 100. For example, a scanning instrument accurate to 0.01 mm is used to obtain a sectional view of Fig. 1. In Fig. 1, the upper surface 101 of the casting 100 is an irregular surface. For easy description, it is assumed that in actual use, only this irregular surface 101 is worn and other surfaces are not worn, or the wear of other surfaces can be ignored. However, the present invention is not limited to this and the method of the present invention can also be used in a situation where a plurality of surfaces of the casting are worn.

[0020] The condition of wear of the casting 100 during use is simulated in a laboratory. The upper surface 101 of the casting 100 shown in Fig. 1 is ground (or used) so that the upper surface 101 of the casting 100 is worn until the limit of service life of the casting 100 is reached. The foregoing scanner is used to scan the casting that has reached the limit of service life to obtain a sectional contour diagram of a worn casting 200 that has been used to a limit state as shown in Fig. 2. The casting 200 in a limit state has an upper surface 201. Fig. 2 is a sectional contour diagram of the casting 200 that can still be used normally and is in a state of wear limit. That is to say, on the basis of the sectional contour diagram of Fig. 2, if the upper surface 201 of the casting 200 is further worn any more, the casting 200 will be scrapped.

[0021] Fig. 3 is a comparison diagram of the sectional contours before and after wear obtained by overlapping the sectional views in Fig. 1 and Fig. 2. In Fig. 3, the shaded area represents the difference between the two sectional views, that is, the shaded area 110 represents the worn-off portion of the casting 100. It can be seen from Fig. 3 that the amount of worn-off substance 110 of the casting 100 (i.e., the thickness worn off) varies with locations. Although Fig. 1 to Fig. 3 only show the two-dimensional sections of the casting, three-dimensional shapes of the casting (unworn and worn) can be obtained through scanning, and by comparing the three-dimensional shape of the unworn casting 100 with the three-dimensional shape of the casting 200 that has been worn to the limit, the three-dimensional shape of the worn-off substance 110 can be obtained.

[0022] In the foregoing embodiment, the worn casting 200 that has been used to a limit state as shown in Fig. 2 is obtained through simulation in a laboratory. The present invention is not limited to it. For a part used after it is installed on an apparatus, the part can be removed from the apparatus after it has been used and worn to a limit state (or approximate to a limit state), and then is scanned with a scanner to obtain a sectional view (or three-dimensional contour data) of the casting 200 that is worn to a limit state (or approximate to a limit state) as shown in Fig. 2.

[0023] After the contour data of the worn-off substance 110 is obtained as described above, a hard surface is manufactured according to the contour data of the worn-off substance 110 so that the manufactured hard surface and the worn-off substance 110 have the same contour.

[0024] Specifically, the external surfaces of the shaded area 110 in Fig. 3, including the upper surface 101 and the lower surface 201, are both known, and data of these external surfaces are obtained by scanning as described above. In an embodiment, a first mold is made according to the shaded area 110 in Fig. 3. The first mold has an inner cavity in a shape same as the contour of the worn-off substance 110. A material for hard surface is melted and poured into the first mold, i.e., injected into the cavity. After the material for hard surface is cooled, a hard surface 120 is obtained, as shown in Fig. 4. The hard surface 120 and the worn-off portion in Fig. 3, i.e., the shaded area 110, have the same shape. As shown in Fig. 4, the hard surface 120 has an upper surface 121 and a lower surface 122. The upper surface 121 is the same as the unworn upper surface 101 of the casting 100 shown in Fig. 1 and the lower surface 122 of the hard surface 120 is the same as the upper surface 201 of the casting 100' that is worn to the limit as shown in Fig. 2.

[0025] Next, a second mold is made according to the shape of the casting 100. The second mold has an inner cavity in a shape same as the casting 100.

[0026] Then the hard surface is arranged on a corresponding side of the inner cavity of the second mold, so that the upper surface 121 of the hard surface 120 is attached to a side wall of the inner cavity with the same shape. Then, molten steel is poured into the mold (the present invention does not limit the material to molten steel, as long as the material is the same as the material constituting the casting 100). After the molten steel is cooled, the steel is solidified to the lower surface of the hard surface 120 to form a complete casting 100', as shown in Fig. 5.

[0027] Fig. 5 is a schematic sectional view of a casting 100' arranged with a hard surface 120 and manufactured according to this embodiment. The appearance of the casting 100' with a hard surface is the same as that of the casting 100 shown in Fig. 1, but the uppermost part of the casting 100' in Fig. 5 is a hard surface 120 made of a wear-resistant material, while the casting 100 in Fig. 1 does not have a hard surface. Except for the hard surface 120, the materials for other parts of the casting 100' shown in Fig. 5 are the same as the casting 100. Further, the sectional view of the casting 100' arranged with a hard surface 120 in Fig. 5 looks similar to Fig. 3, but the shaded area 110 in Fig. 3 represents the material that is worn away, while the shaded area 120 in Fig. 5 represents a hard surface.

[0028] Then, the casting 100' is scanned to obtain its contour data (it is the same as the contour of the casting 100. Alternatively, the contour data of the casting 100 can be used to substitute the contour data of the casting 100').

[0029] Next, the situation where the casting 100 is worn in the use state is simulated again and the casting 100' with a hard surface manufactured above is ground (the inventors of the present invention performed simulated grounding in the laboratory). The grinding method is the same as the foregoing grinding method for the casting 100 without a hard surface. After the casting 100' with the hard surface 120 is worn to a limit state (compared to the embodiment shown in Fig. 1, it takes a longer time to reach a state of wear limit because the hard surface is arranged in this embodiment), a scanner is used to obtain a contour diagram of the casting 100'. The contour diagram of the casting 100' that has been worn to a limit state is shown as the solid curve in Fig. 6. This contour is very similar to the contour of the casting 100 not having a hard surface and worn to a limit state as shown in Fig. 2. Then, the contour diagram is overlapped with the sectional contour diagram without wear to form a comparison diagram of sectional contours before and after wear. The comparison diagram of sectional contours is overlapped with the comparison diagram of sectional contours of the casting 100 without a hard surface before and after wear as shown in Fig. 3 to obtain Fig. 6. Among them, the contour curve with wear to a limit state in Fig. 3 is shown as a dashed line and the contour curve with wear to a limit state after the hard surface is arranged in this embodiment is shown as a solid line. It can be seen from Fig. 6 that the sectional contour of the casting 100 with a hard surface cast according to the present invention in a state of wear limit (solid line) is very similar to the sectional contour of the casting 100 without a hard surface in a state of wear limit (dash line). In other words, the hard surface 120 arranged in the casting 100' according to the present invention can be completely worn away in actual use. This is because the present invention has precisely designed the shape of the hard surface 120.

[0030] In contrast, in the prior art, due to inaccurate design of the hard surface, some locations of the hard surface of the casting have been worn through (in other words, the hard surface material is completely worn away), resulting in scrapping of the casting, while some locations of the hard surface are still very thick, so when the casting is scrapped, there is still a lot of hard surface material remaining on the casting. As the more wear-resistant hard surface material is relatively expensive, this increases the cost of casting manufacturing in the prior art. The present invention designs the shape of the hard surface 120 reasonably and accurately, so that when the casting 100' reaches the wear limit, the hard surface 120 is basically completely worn away, thereby making full use of the hard surface material.

[0031] By referring to the flow diagram shown in Fig. 7, a method for manufacturing a casting arranged with a hard surface according to an embodiment of the present invention is introduced below.

[0032] At step S1100, an unworn casting 100 is scanned, for example, with a scanner, to obtain contour data of the casting 100. The contour data can be spatial coordinates of the points on the outer surface of the casting 100. At step S1200, a casting 200 in a state of wear limit is scanned to obtain contour data of the casting 200. At step S1300, the contour data of the unworn casting 100 is compared with the contour data of the casting 200 in a state of wear limit to obtain contour data of the worn-off substance, for example, obtain contour data of the shaded area shown in Fig. 3. At step S1400, a hard surface is manufactured according to the contour data of the worn-off substance obtained at the step S1300 so that the contour of the hard surface is the same as the contour of the worn-off substance. In an embodiment, the step S1400 includes making a first mold according to the contour data of the worn-off substance and then pouring molten wear-resistant substance into the mold to obtain a hard surface after the wear-resistant substance is cooled and shaped.

[0033] The subsequent steps also include making a second mold according to the shape of the unworn casting 100, putting the completed hard surface into the second mold to keep the top surface of the hard surface fit the corresponding surface of the second mold, injecting molten steel (as required, it can be an alloy molten liquid made of other components), taking it out from the mold after the molten steel is cooled and solidified to a side of the hard surface, to obtain a casting with a hard surface.

[0034] The above has introduced an embodiment of the present invention for arranging a hard surface on a casting. Alternatively, in other embodiments, a plurality of hard points can be used instead of a hard surface and a plurality of hard points can be arranged in a regular density (in other embodiments, the density of hard points can be irregular, too) to form a hard surface that can tally with natural wear. Such hard surface formed by points can retain a contour of limit wear and at the same time increase the service life of the product and optimize the layout of the hard surface. It replaces the conventional design of fixed hard surface. The so-called hard points are shaped columns with a certain length formed by a wear-resistant material, or a plurality of particles formed by a wear-resistant material. The so-called hard points are columns with a certain length made of a wear-resistant material and the columns extends downward from a surface 101 of the casting to be worn (towards the inside of the casting). As the material constituting the hard points is more wear-resistant than the material constituting the casting 100, a number of hard points are arranged on the surface 101 of the casting 100.

[0035] Fig. 8 is a schematic sectional view of a casting 100" arranged with a plurality of hard points 160 according to an embodiment of the present invention. The contour of the casting 100" in the figure is same as that of the casting 100 shown in Fig. 1 and that of the casting 100' shown in Fig. 5. Particularly, the upper surface 121 of the casting 100" is the same as the upper surface 101 of the casting 100 in Fig. 1. In this figure, the hard points 160 are shown as black columns. Every hard point 160 is made of a wear-resistant material to improve the wear resistance of the casting 100". A plurality of the hard points 160 are equally spaced and extend downward from a top surface 121 of the casting 100" (it is also called as a longitudinal direction. The direction perpendicular to it is called a horizontal direction). Each hard point 160 has an upper end and a lower end and the length of each hard point 160 corresponds to the thickness at a corresponding location of the hard surface 120 shown in Fig. 4. In other words, the hard points 160 are arranged in such a way that the upper surface 121 of each hard point 160 is the same as the upper surface 121 of the hard surface 120 in Fig. 4 and the lower surface 122 of each hard point 160 is the same as the lower surface 122 of the hard surface 120 in Fig. 4.

[0036] The hard points are manufactured by bonding particles of a wear-resistant material (also known as hard point particles) together through a bonding substance to form columns with a certain length and cross section. The length of a hard point refers to the longitudinal length of the columnar hard point, or in other words, the length of the hard section of a columnar body formed by hard point particles. According to the existing technology, the minimum hard points are 1.5 mm in diameter and the fusible bonding spacing (i.e., the distance between adjacent hard points) can be reduced to 1 mm. The maximum hard points can be up to 100 mm in diameter. As their specific gravity is large, the fusible bonding spacing must be at least 100 mm. In a preferred embodiment of the present invention, each of the columns is 16 to 20 mm in diameter and there is a distance of 20 to 25 mm between adjacent hard points.

[0037] In practical applications, the length of hard points will be limited. If the length of the hard points is too large, the hard points cannot be firmly fused with the casting. That is to say, in practical applications, the length of the hard points has an upper limit, i.e., the maximum usable length of hard points. If the worn length (or depth) at some locations of the extremely worn surface exceeds the maximum usable length of hard points, the arrangement of each hard point should be reduced in proportion to the maximum usable length to ensure that the contour of wear limit is basically consistent with the original casting.

[0038] Fig. 9 shows such an embodiment. Fig. 9 and Fig. 8 show the same unworn surface 121 of a casting. The difference between Fig. 9 and Fig. 8 is that in Fig. 8, the location of the surface 122 in a state of wear limit is shallower, while in Fig. 9, the location of the surface 122 in a state of wear limit is deeper, so that the thickness of the worn-off portion of the casting exceeds the maximum usable length of hard points. For example, the hard point at A_1-A_3 in Fig. 9 has the maximum usable length. At this location, the thickness of final wear is the thickness of A_1-A_2, greater than the maximum usable length of the hard point at A_1-A_3. Below the setting of the length of each hard point in this case is introduced.

[0039] Further, by referring to Fig. 9, the hard point at B_1-B_3 is taken as an example to introduce a method for determining the length of each hard point. Let the distance from point A_1 to point A_2 be d_A, which is the thickness of the casting that is finally worn at point A; and the distance from point B_1 to point B_2 be d_B, which is the thickness of the casting that is finally worn at point B. It is assumed that the wearing rate of all locations (all points) of a component is constant during the process from an unworn state to a state of wear limit. It is assumed that the wear rate at point A is V_A and the wear rate at point B is V_B and the two satisfy the following relation:

$$V_A/V_B = d_A/d_B \qquad (1)$$

[0040] Let the length from point A_1 to point A_3, i.e., the length of hard point A, be L_A, and the length from point B_1 to point B_3, i.e., the length of hard point B, be L_B, and the two satisfy the following relation:

$$L_A/L_B = d_A/d_B$$

i.e., the length of the hard point at point B is:

$$L_B = d_B * L_A/d_A \qquad (2)$$

[0041] In other words, the length L_B of each hard point should be set according to Formula (2). In Fig. 9, point A is a reference point. At point A, the depth of final wear is greater than or equal to the maximum usable length of hard points. Further, in the figure, point B is adjacent to point A, and this is just an example. In fact, point B can be at any location of the casting and the hard point at point B represents any hard point on the casting.

[0042] Below the method of manufacturing a casting with hard points according to an embodiment of the present invention with reference to the flow diagram shown in Fig. 10.

[0043] Steps S2100, S2200 and S2300 in Fig. 10 are the same as corresponding steps S1100, S1200 and S 1300 in Fig. 7 and are not described in detail herein. Below the differences between the flow diagram shown in Fig. 10 and the flow diagram shown in Fig. 7 are introduced.

[0044] At step S2400, calculate the total number of hard points and the coordinates of each hard point on the horizontal plane according to the density of hard points to be arranged. The horizontal plane here refers to a plane perpendicular to the longitudinal direction of hard points 160 in Fig. 8.

[0045] At step S2500, calculate the longitudinal length of each hard point according to the contour data of the worn-off portion and the calculated coordinates of each hard point on the horizontal plane. The longitudinal length of each hard point corresponds to the distance between the unworn surface 101 and the surface 201 in a state of wear limit shown in Fig. 3 at the coordinates of this hard point.

[0046] At step S2600, manufacture columnar hard points with a corresponding length and required diameter. Various methods in the prior art can be used to manufacture the hard points. In this embodiment, the diameter (or cross-section) of each of the columnar hard points is the same.

[0047] At step S2700, fix the manufactured hard points to corresponding coordinates in the mold. It is clear to those skilled in the art that various methods in the prior art can be used to fix each hard point.

[0048] The subsequent steps also include pouring molten steel into a mold arranged with hard points (alternatively, it can be an alloy molten liquid made of other components). The molten steel will enter spaces among the hard points. After the molten steel is cooled and solidified with each hard point into a body, it is taken out from the mold to obtain a casting arranged with hard points.

[0049] The above figures show two-dimensional sectional views of a casting. Those skilled in the art can readily understand that a scanner can be used to scan the casting surface, thereby obtaining a curved surface of the casting distributed in a three-dimensional space. According to the curved surfaces of the casting distributed in a three-dimensional space before and after wear of the casting, a three-dimensional distribution of a hard surface or hard points can be manufactured.

[0050] It can be seen from the foregoing introduction that the design basis of hard surface and hard points of the present invention is to ensure the contour of a casting manufactured according to the present invention in a state of wear limit is the same as or consistent with the contour of the original casting in a state of wear limit, thereby assuring the stability and use safety of the product as an accessory. The casting manufactured using the hard surface casting technology of the present invention not only is wear resistant (because a hard surface or hard points are added) but also the sectional contour in a state of wear limit is basically consistent with the sectional contour of the casting without a hard surface or hard points in a state of wear limit, thereby making full use of the added wear-resistant material, further prolonging the service life of the casting and reducing manufacturing cost.

[0051] In another aspect of the present invention, the properties of a material for hard surface or hard points are selected according to the properties of the material for casting 100. According to the defects of the existing mechanical properties of the material for casting 100, a material for hard surface or hard points is selected in a targeted manner. The purpose is to make up for the existing defects of the product through material upgrading of the surface or points, thereby improving the overall performance and service life of the casting.

[0052] In an embodiment, the mechanical properties of the selected material for hard surface or hard points are the same as or similar to those of the original casting material. This can ensure that after the hard surface or hard points are formed, the entire product will not have other unexpected wear curves due to difference between the worn surface and other surfaces in mechanical properties, resulting in unstable overall performance of the product.

[0053] In an alternative embodiment, the selected material for hard surface or hard points is more corrosion resistant than the original casting material.

[0054] Although the present invention is described through specific embodiments, those skilled in the art should understand that various changes and equivalent replacements can be made to the present invention without departing from the scope of the present invention. In addition, for specific situations or materials, various modifications can be made to the present invention without departing from the scope of the present invention. Therefore, the present invention is not limited to the disclosed specific embodiments, but should include all the implementation manners falling within the scope of the disclosure herein of the present invention.

Claims

1. A casting manufacturing method, comprising:

obtaining contour data of an unworn casting;
obtaining contour data of the casting in a state of wear limit;
obtaining contour data of the worn-off portion according to the contour data of the unworn casting and the contour data of the casting in a state of wear limit; and
manufacturing a hard surface according to the contour data of the worn-off portion so that the manufactured hard surface and the worn-off portion have substantially the same contour.

2. The manufacturing method according to claim 1, further comprising,
putting the manufactured hard surface into a mold, and
pouring molten steel or alloy into the mold so that the cooled molten steel or alloy is combined with the hard surface to form a casting with a hard surface.

3. The manufacturing method according to claim 1 or 2, wherein the material constituting the hard surface is more wear resistant than the materials for other parts of the casting.

4. The manufacturing method according to any one of claims 1 to 3, wherein the material constituting the hard surface and the materials for other parts of the casting have similar mechanical properties.

5. The manufacturing method according to any one of claims 1 to 3, wherein the material constituting the hard surface is more corrosion resistant than the materials for other parts of the casting.

6. The manufacturing method according to any one of claims 1 to 5, wherein the step of obtaining contour data of the casting in a state of wear limit comprises, scanning the casting that is worn approximately to a limit state in actual use to obtain its contour data; or, manually grinding the casting in a simulated use state, and scanning the casting when it is worn approximately to a limit state to obtain its contour data.

7. The manufacturing method according to any one of claims 1 to 6, wherein:
the step of manufacturing a hard surface according to the contour data of the worn-off portion comprises:

calculating the total number of hard points and the coordinates of each hard point on the horizontal plane according to the maximum fusible pasting density of molten steel or alloy and hard points;
calculating the length of each hard point according to the contour data of the worn-off portion and the coordinates of each hard point;
manufacturing hard points with a corresponding length and required transverse section;
fixing the plurality of hard points to corresponding coordinates in the mold respectively, with the length of each hard point being consistent with the thickness at the corresponding location of the contour data of the worn-off portion; and
pouring molten steel or alloy into the mold so that the cooled molten steel or alloy is combined with the hard points to form a casting with hard points.

8. The manufacturing method according to claim 7, wherein when the thickness of final wear exceeds the maximum usable length of hard points, the step of calculating the length of each hard point comprises:

selecting a reference point A, where the hard point has the maximum usable length L_A, determining the length of any other hard point B according to the following formula,

$$L_B = d_B * L_A / d_A \qquad (2)$$

where, L_B is the length of hard point B, d_A is the thickness of final wear at point A and d_B is the thickness of final wear at point B.

9. The manufacturing method according to claim 7 or 8, wherein,
the diameter of each hard point is 1.5 to 100 mm.

10. The manufacturing method according to claim 9, wherein,
the diameter of each hard point is 16 to 20 mm and the distance between two adjacent hard points is 20 to 25 mm.

11. The manufacturing method according to any one of claims 7 to 10, wherein the material constituting the hard points and the materials for other parts of the casting have similar mechanical properties.

12. A casting, manufactured by a method according to any one of the preceding claims.

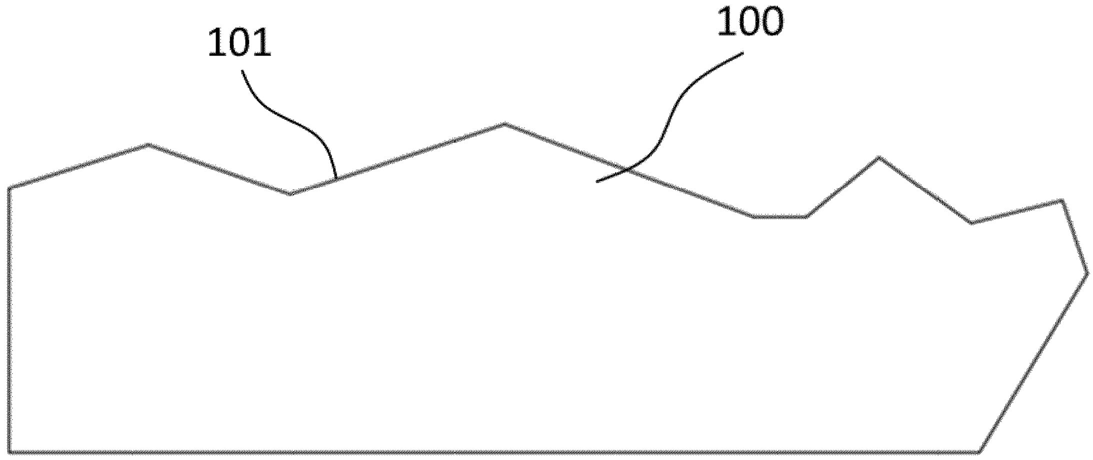


Fig. 1

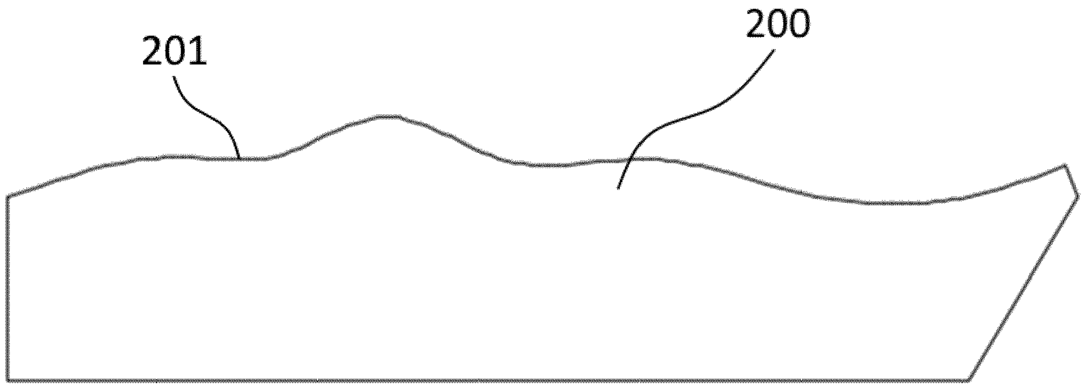


Fig. 2

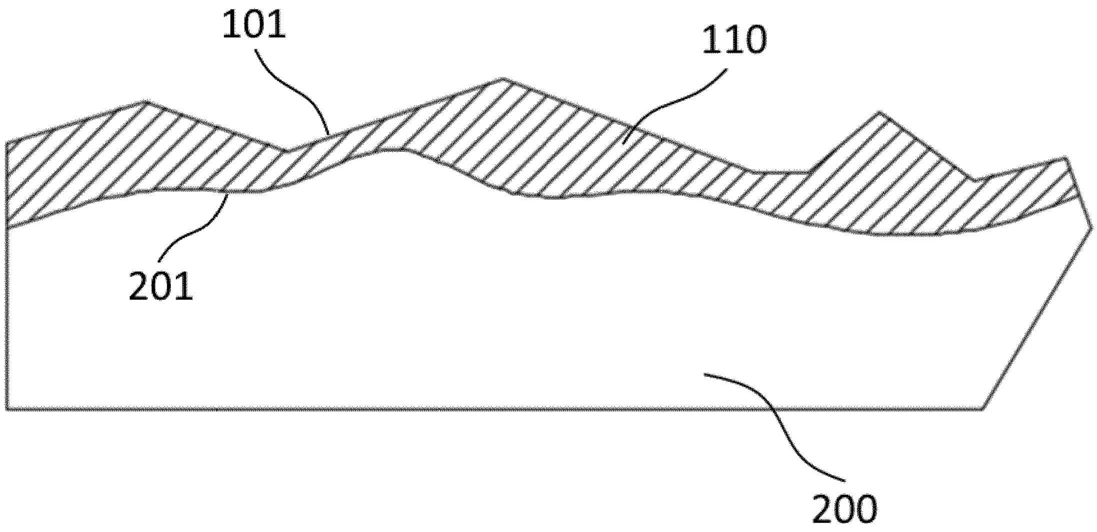


Fig. 3

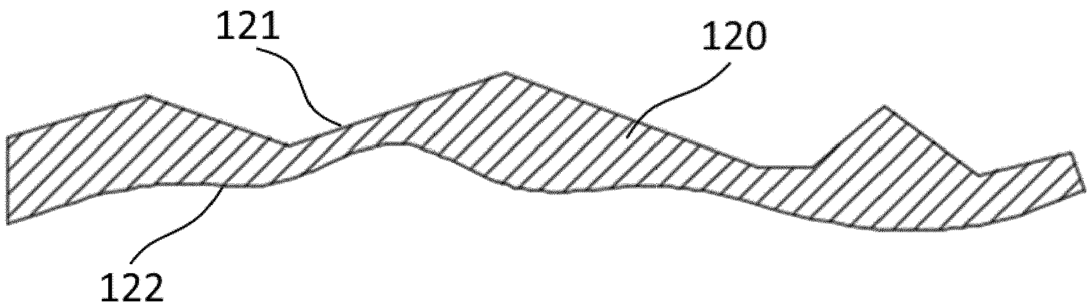


Fig. 4

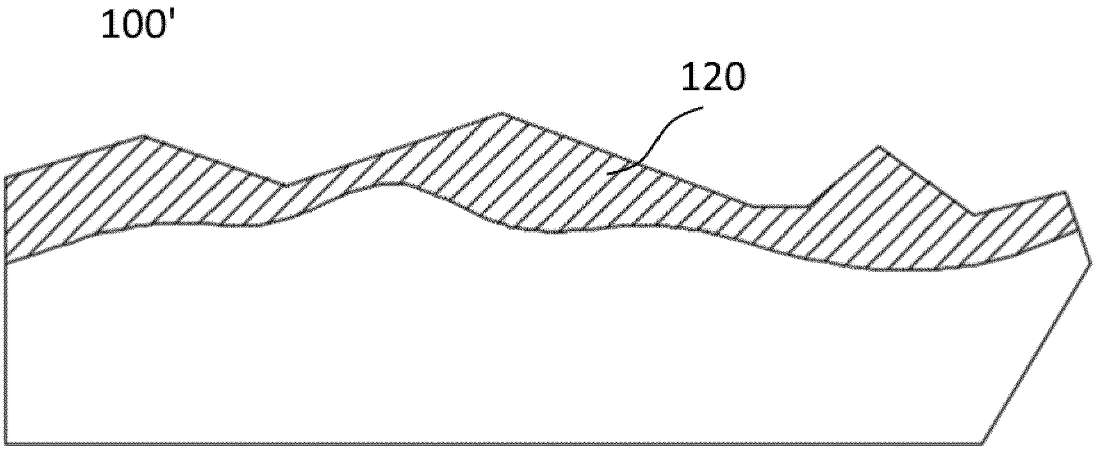
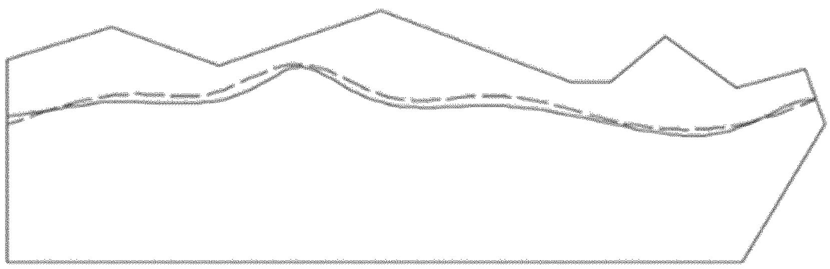


Fig. 5



Wear diagram generated by scanning before arrangement of a hard surface

Wear diagram generated by scanning again after arrangement of a hard surface and use

Fig. 6

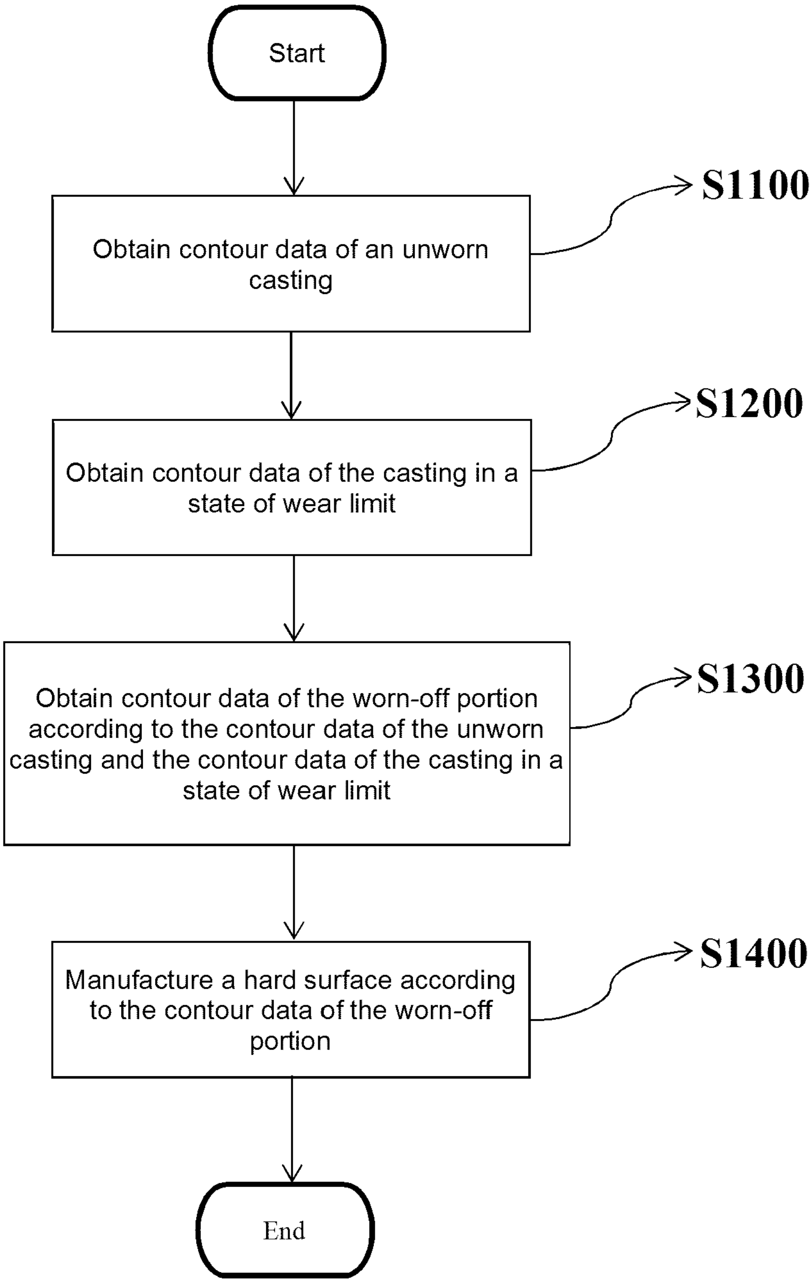

Start
Obtain contour data of an unworn casting
S1100
Obtain contour data of the casting in a state of wear limit
S1200
Obtain contour data of the worn-off portion according to the contour data of the unworn casting and the contour data of the casting in a state of wear limit
S1300
Manufacture a hard surface according to the contour data of the worn-off portion
S1400
End

Fig. 7

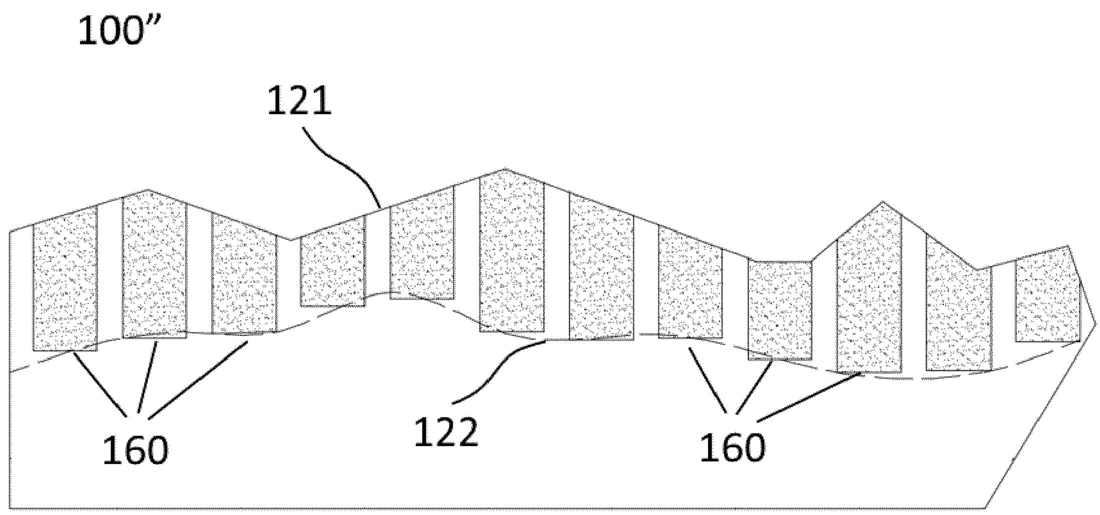


Fig. 8

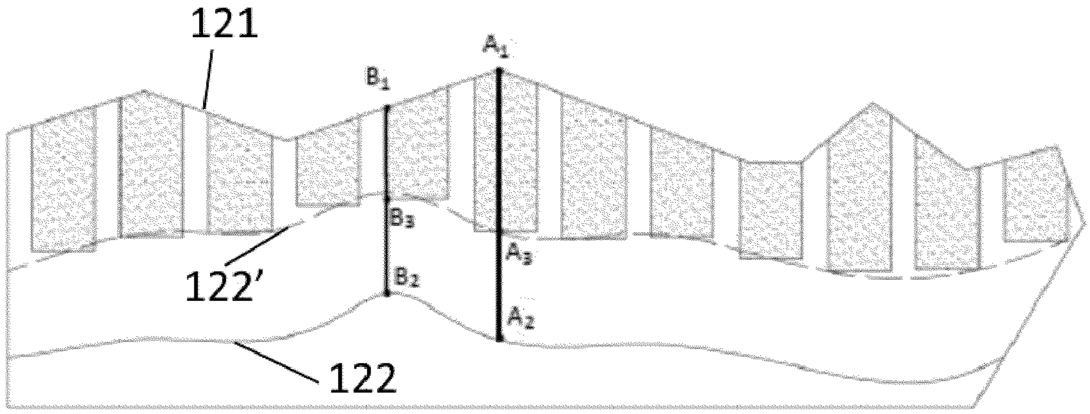


Fig. 9

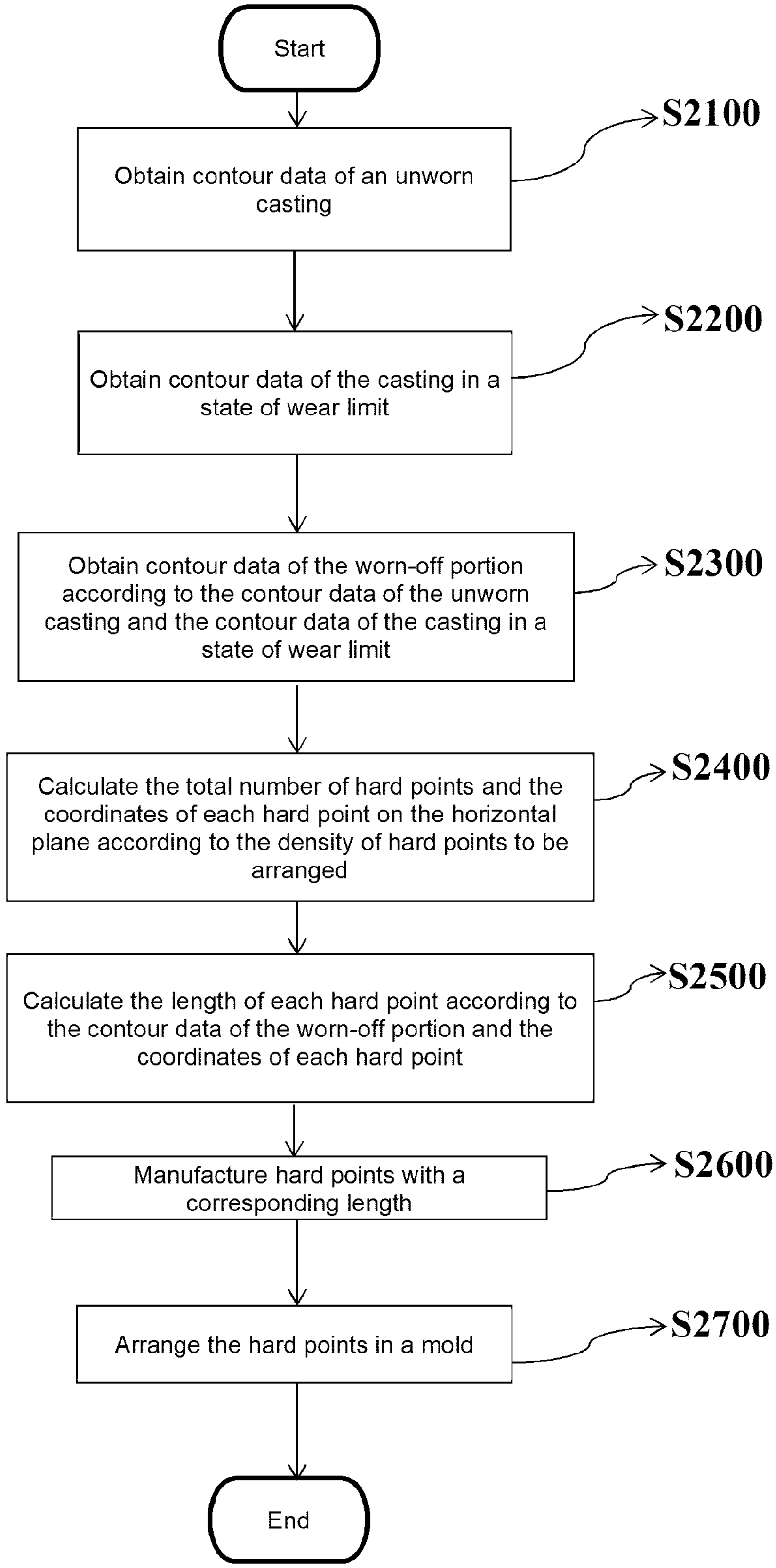

Start
S2100
Obtain contour data of an unworn casting
S2200
Obtain contour data of the casting in a state of wear limit
S2300
Obtain contour data of the worn-off portion according to the contour data of the unworn casting and the contour data of the casting in a state of wear limit
S2400
Calculate the total number of hard points and the coordinates of each hard point on the horizontal plane according to the density of hard points to be arranged
S2500
Calculate the length of each hard point according to the contour data of the worn-off portion and the coordinates of each hard point
S2600
Manufacture hard points with a corresponding length
S2700
Arrange the hard points in a mold
End

Fig. 10

European Patent Office / Europäisches Patentamt / Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 21 15 6550

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	US 5 081 774 A (KUWANO YUKIMITSU [JP]) 21 January 1992 (1992-01-21) * column 3, line 55 - column 5, line 29; figures 1-6, 8, 9 *	12 1-11	INV. B22D19/02 B22D19/06 B22D19/08
X A	US 2015/299827 A1 (EDERYD STEFAN [SE]) 22 October 2015 (2015-10-22) * paragraph [0031] * * paragraph [0012] - paragraph [0031] * * figures 1-3 *	12 1-11	
X A	EP 2 435 636 A1 (METALOGENIA SA [ES]) 4 April 2012 (2012-04-04) * figures 1-3 * * claims 1-15 * * paragraph [0008] - paragraph [0012] * * paragraph [0014] - paragraph [0031] *	12 1-11	
X A	US 2017/241108 A1 (BARLOW J O; DEAN A M; KOKOS G B; MAJEWSKI T; TASOVSKI V; YANIAK T) 24 August 2017 (2017-08-24) * paragraph [0040] - paragraph [0059]; figures 3-9 *	12 1-11	TECHNICAL FIELDS SEARCHED (IPC) B22D

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
The Hague	22 July 2021	Pipoli, Tiziana

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

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 15 6550

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

22-07-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5081774 A	21-01-1992	CA 1309741 C	03-11-1992
		JP 2596106 B2	02-04-1997
		JP H02176026 A	09-07-1990
		US 5081774 A	21-01-1992
US 2015299827 A1	22-10-2015	CN 104797722 A	22-07-2015
		DK 2917379 T3	30-01-2017
		EP 2917379 A1	16-09-2015
		EP 3012336 A1	27-04-2016
		ES 2609989 T3	25-04-2017
		ES 2734997 T3	13-12-2019
		JP 6281959 B2	21-02-2018
		JP 2015537118 A	24-12-2015
		KR 20150070231 A	24-06-2015
		PL 2917379 T3	31-03-2017
		PT 2917379 T	06-01-2017
		PT 3012336 T	21-06-2019
		US 2015299827 A1	22-10-2015
		WO 2014072932 A1	15-05-2014
EP 2435636 A1	04-04-2012	AU 2010252229 A1	15-12-2011
		CA 2762933 A1	02-12-2010
		CN 102482862 A	30-05-2012
		EP 2435636 A1	04-04-2012
		ES 2472917 T3	03-07-2014
		PL 2435636 T3	30-09-2014
		RU 2011147743 A	10-07-2013
		US 2012131821 A1	31-05-2012
		WO 2010136208 A1	02-12-2010
		ZA 201108682 B	25-07-2012
US 2017241108 A1	24-08-2017	US 2017241108 A1	24-08-2017
		WO 2017142829 A1	24-08-2017

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- CN 202010112564X **[0001]**
- CN 2020256420 **[0001]**