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(54) PISTON, DEVICE FOR MANUFACTURING PISTONS, AND METHOD FOR MANUFACTURING PISTONS

(57) Provided are a piston, a piston manufacturing device, and a piston manufacturing method. The piston includes a piston base (100), a porous function layer (101), a micropore filling layer (102), and a closing layer (103). The porous function layer (101) is disposed on a top surface of the piston base (100). The micropore filling layer (102) is disposed on a top surface of the porous function layer (101). The diameter of a pore in the micropore filling layer (102) is smaller than the diameter of a pore in the porous function layer (101). The closing layer (103) is disposed on a top surface of the micropore filling layer (102) and configured to partially block the pores in the micropore filling layer (102).

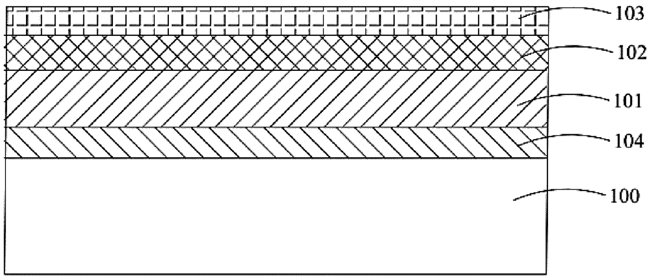

FIG. 1

Description

TECHNICAL FIELD

[0001] The present application relates to the field of machining technology, for example, a piston, a piston manufacturing device, and a piston manufacturing method.

BACKGROUND

[0002] With excellent features including low density, sound thermal conductivity, and high strength, aluminum alloy has been widely used in fields related to the manufacturing of pistons of internal combustion engines. Compared with traditional steel pistons and cast iron pistons, aluminum alloy pistons have a series of advantages in the application of internal combustion engines, such as high power, low vibration, little wear, and strong corrosion resistance. However, with the development and renewal of internal combustion engine technology, defects of the aluminum alloy pistons are gradually exposed, for example, low thermal strength and poor mechanical properties at high temperatures. Under the action of high-strength thermal shock cycles, the aluminum alloy pistons often suffer from failure problems like ablation and corrosion.

[0003] In the current piston protection technology, thermal insulation technology is mostly used, protecting bases and increasing the temperature in combustion chambers. When a piston after being thermally insulated works, the heat transferred to the cooling water through the surface of a combustion chamber is reduced. Correspondingly, the heat transfer loss carried away by the cooling water reduces, both reducing the energy loss and improving the efficiency of an internal combustion engine. However, with the development of thermal insulation technology, the thermal insulation performance of a thermal insulation material improves gradually. The excellent thermal insulation performance protects a base. Nonetheless, due to the large volumetric heat capacity of the thermal insulation material, the piston is not easily heated. The air inlet temperature of cold air entering the combustion chamber is relatively high. Correspondingly, combustion temperature rises. When the combustion temperature rises to a certain extent, the gas molecular spacing in the combustion chamber is enlarged, leading to a reduction in the air intake amount in an intake stroke, thereby reducing a fuel-air ratio and combustion efficiency.

[0004] Additionally, in the existing manufacturing of a plasma oxide coating, the concentration may be increased by adding solute so as to implement traditional electrolyte adjustment. However, when the concentration needs to be reduced or when solutions with different ratios are provided in different growth stages of the plasma oxide coating, a reaction needs to be interrupted and an electrolyte is re-prepared, increasing the manufacturing time and cost.

SUMMARY

[0005] The present application provides a piston with a sound thermal insulation performance and sound corrosion resistance so as to implement the protection performance of controlling combustion temperature.

[0006] The present application provides a piston, a piston manufacturing device, and a piston manufacturing method so that installation and disassembly are not needed repeatedly, saving the manufacturing cost.

[0007] An embodiment provides a piston. The piston includes a piston base, a porous function layer, a micropore filling layer, and a closing layer.

[0008] The porous function layer is disposed on a top surface of the piston base.

[0009] The micropore filling layer is disposed on a top surface of the porous function layer. The diameter of each of pores in the micropore filling layer is smaller than the diameter of each of pores in the porous function layer.

[0010] The closing layer is disposed on a top surface of the micropore filling layer and configured to partially block pores in the micropore filling layer.

[0011] Embodiments of the present application further provide a piston manufacturing device configured to manufacture the preceding piston. The piston manufacturing device includes a clamp, a power supply, a first reaction mechanism, a second reaction mechanism, and a third reaction mechanism.

[0012] The clamp is configured to clamp a piston base. A top of the piston base sealingly extends into the clamp and forms a sealing cavity with an inner wall of the clamp.

[0013] An anode of the power supply is electrically connected to the piston base. A cathode of the power supply is electrically connected to the clamp.

[0014] The first reaction mechanism selectively communicates with the sealing cavity so as to form a porous function layer on a top surface of the piston base.

[0015] The second reaction mechanism selectively communicates with the sealing cavity so as to form a micropore filling layer on a top surface of the porous function layer.

[0016] The third reaction mechanism selectively communicates with the sealing cavity so as to form a closing layer on a top surface of the micropore filling layer.

[0017] Embodiments of the present application further provide a piston manufacturing method for manufacturing a piston by using the preceding piston manufacturing device. The piston manufacturing method includes the steps below.

[0018] A clamp is used for sealingly clamping a piston base, and a sealing cavity is formed between the piston base and an inner wall of the clamp.

[0019] An anode of a power supply is electrically connected to the piston base. A cathode of the power supply is electrically connected to the clamp.

[0020] A first reaction mechanism is opened and a second reaction mechanism and a third reaction mechanism are closed so that the first reaction mechanism communicates with the sealing cavity, and a porous function layer is formed on a top surface of the piston base by using an electrochemical manner.

[0021] The second reaction mechanism is opened, and the first reaction mechanism and the third reaction mechanism are closed so that the second reaction mechanism communicates with the sealing cavity, and a micropore filling layer is formed on a top surface of the porous function layer by using the electrochemical manner.

[0022] The third reaction mechanism is opened, and the first reaction mechanism and the second reaction mechanism are closed so that the third reaction mechanism communicates with the sealing cavity, and a closing layer covering a top surface of the micropore filling layer is formed.

BRIEF DESCRIPTION OF DRAWINGS

[0023]

FIG. 1 is a structural diagram of a piston according to the present application.
FIG. 2 is a structural diagram of a piston manufacturing device according to the present application.
FIG. 3 is a flowchart of a piston manufacturing method according to the present application.

<u>Reference list</u>

[0024]

100	piston base
101	porous function layer
102	micropore filling layer
103	closing layer
104	adhesive layer
1	clamp
2	power supply
3	first reaction mechanism
4	second reaction mechanism
5	third reaction mechanism
6	sealing ring
7	fixed ring
8	hydraulic pump
9	three-way valve
10	pump
11	first vacuum valve
12	second vacuum valve
31	first reaction box
32	first valve
41	second reaction box
42	second valve
51	third reaction box
52	third valve

DETAILED DESCRIPTION

[0025] In the description of the present application, unless otherwise expressly specified and limited, the term "connected to each other", "connected" or "secured" is to be construed in a broad sense, for example, as securely connected, detachably connected, or integrated; mechanically connected or electrically connected; directly connected to each other or indirectly connected to each other via an intermediary; or internally connected between two components or interaction relations between two components. For those of ordinary skill in the art, specific meanings of the preceding terms in the present application may be construed according to specific circumstances.

[0026] In the present application, unless otherwise expressly specified and limited, when a first feature is described as "above" or "below" a second feature, the first feature and the second feature may be in direct contact or be in contact via another feature between the two features instead of being in direct contact. Moreover, when the first feature is described as "on", "above", or "over" the second feature, the first feature is right on, above, or over the second feature or the first feature is obliquely on, above, or over the second feature, or the first feature is simply at a higher level than the second feature. When the first feature is described as "under", "below", or "underneath" the second feature, the first feature is right under, below, or underneath the second feature or the first feature is obliquely under, below, or underneath the second feature, or the first feature is simply at a lower level than the second feature.

[0027] For an existing aluminum alloy piston, many penetrating or semi-closed gap channels exist on the surface of a porous structure coating of the piston. In a combustion chamber of the aluminum alloy piston, heat convection may be generated in such semi-open channels, resulting in a poor thermal insulation performance of the coating. Additionally, in the combustion chamber, combustion heat and combustion products corrode the surface of the aluminum alloy piston. A corrosive medium easily penetrates the channels and corrodes the channels, resulting in an erosion of a protective material or an erosion of the piston and reducing the corrosion resistance of the piston.

[0028] To solve this problem, this embodiment provides a piston. As shown in FIG. 1, the piston includes a piston base 100, a porous function layer 101, a micropore filling layer 102, and a closing layer 103. The piston base 100 is optionally made of an aluminum alloy material. The porous function layer 101 is disposed on a top surface of the piston base 100. The porous function layer 101 is a loose porous layer structure. The micropore filling layer 102 is disposed on a top surface of the porous function layer 101. The diameter of each ofpores in the micropore filling layer 102 is smaller than the diameter of each of pores in the porous function layer 101. The closing layer 103 is disposed on a top surface of the micropore filling layer 102 and configured to partially block pores in the micropore filling layer 102. The closing layer 103 performs the function of blocking.

[0029] For the piston provided in this embodiment, the porous function layer 101 is disposed in the top surface of the piston base 100. The micropore filling layer 102 is disposed in the top surface of the porous function layer 101. The pores in the micropore filling layer 102 and the pores in the porous function layer 101 form channels. The channels are used for storing air and play the function of thermal insulation. The diameter of each of pores in the micropore filling layer 102 is smaller than the diameter of each of pores in the porous function layer 101. In this case, the micropore filling layer 102 performs a transition between the porous function layer 101 and the closing layer 103 and fills the porous function layer 101 to a certain extent. The closing layer 103 is disposed on the top surface of the micropore filling layer 102 and configured to block the pores in the micropore filling layer 102. Accordingly, the closing layer 103 performs the function of blocking, preventing a corrosive medium from entering the pores of the porous function layer 101 and the pores of the micropore filling layer 102 to corrode the porous function layer 101 and the micropore filling layer 102, protecting the piston base 100, and thereby improving the corrosion resistance of the piston.

[0030] Additionally, with the coordination of the porous function layer 101 and the micropore filling layer 102, an air layer may be formed in the pores of the porous function layer 101 and the pores of the micropore filling layer 102, effectively reducing the heat capacity of the entire piston, better guaranteeing the performance of thermal insulation and protection, and implementing the protection performance of controlling combustion temperature. In this case, the piston is easily heated. The air inlet temperature of cold air entering a combustion chamber is low, avoiding air-inlet heating, thereby improving the efficiency of converting heat into useful work, and effectively reducing fuel consumption.

[0031] Optionally, to guarantee the coordination of the porous function layer 101 and the micropore filling layer 102, the pores in the micropore filling layer 102 are disposed continuously. Moreover, at least one parameter of porosities of the pores in the micropore filling layer 102 and diameters of the pores in the micropore filling layer 102 is in descending order. The porous function layer 101 enables the piston to obtain a sound thermal insulation performance. The micropore filling layer 102 reduces the thermal conductivity of a coating and serves as a second barrier of an anticorrosive medium. The arrangement in which the pores in the micropore filling layer 102 are in descending order and are disposed continuously can not only maintain a sound structural transition between the porous function layer 101 and the micropore filling layer 102 but also guarantee the implementation of two functions of thermal insulation and low thermal conductivity.

[0032] In the process of forming the porous function layer 101 based on the top surface of the piston base 100, an adhesive layer 104 may be formed between the compact top surface of the piston base 100 and the porous function layer 101. The adhesive layer 104 performs a transition between the piston base 100 and the porous function layer 101.

[0033] To manufacture the preceding piston, this embodiment further provides a piston manufacturing device. As shown in FIG. 2, the piston manufacturing device includes a clamp 1, a power supply 2, a first reaction mechanism 3, a second reaction mechanism 4, and a third reaction mechanism 5. The clamp 1 is configured to clamp the piston base 100. The top of the piston base 100 sealingly extends into the clamp 1 and forms a sealing cavity with an inner wall of the clamp 1. An anode of the power supply 2 is electrically connected to the piston base 100. A cathode of the power supply 2 is electrically connected to the clamp 1. The first reaction mechanism 3 selectively communicates with the sealing cavity so as to form the porous function layer 100 on the top surface of the piston base 101. The second reaction mechanism 4 selectively communicates with the sealing cavity so as to form the micropore filling layer 102 on the top surface of the porous function layer 101. The third reaction mechanism 5 selectively communicates with the sealing cavity so as to form the closing layer 103 on the top surface of the micropore filling layer 102.

[0034] For the piston manufacturing device provided in this embodiment, the clamp 1 has a fixing effect on the piston base 100. The top of the piston base 100 sealingly extends into the clamp 1 to form the sealing cavity. The sealing cavity provides a reaction environment for manufacturing a coating on the top surface of the piston base 100. With the first reaction mechanism 3 selectively communicating with the sealing cavity, the porous function layer 100 is manufactured on the top surface of the piston base 101. With the second reaction mechanism 4 selectively communicating with the sealing cavity, the micropore filling layer 102 is manufactured on the top surface of the porous function layer 101. With the third reaction mechanism 5 selectively communicating with the sealing cavity, the closing layer 103 is manufactured on the top surface of the micropore filling layer 102. With the adoption of this structure, the manufacturing procedure of the porous function layer 101, the manufacturing procedure of the micropore filling layer 102, and the manufacturing procedure of the closing layer 103 are completed in the sealing cavity formed by the specialized clamp 1 and the top of the piston base 100 with no need for installing and disassembling each reaction mechanism, saving the time cost and avoiding the secondary pollution of each coating.

[0035] Exemplarily, the clamp 1 is a box structure. The clamp 1 has an accommodation cavity. A first joint and a second joint are disposed on the top of the clamp 1. The first joint is a liquid inlet. The first joint communicates with the first reaction mechanism 3, the second reaction mechanism 4, and the third reaction mechanism 5 separately so that the liquid in each reaction mechanism enters the sealing cavity through the first joint. The second joint is a liquid outlet. The second joint communicates with the first reaction mechanism 3 and the second reaction mechanism 4 separately so that the liquid completing a reaction in the sealing cavity flows out through the second joint.

[0036] A cathode joint is also disposed on the top of the clamp 1. The cathode of the power supply 2 is electrically connected to the clamp 1 through the cathode j oint. The anode of the power supply 2 is electrically connected to the piston base 100. To guarantee the insulation effect between the piston base 100 and the clamp 1, as shown in FIG. 2, optionally, the piston manufacturing device further includes a sealing ring 6. The sealing ring 6 is an O-shaped sealing ring 6. The sealing ring 6 is made of polytetrafluoroethylene. The sealing ring 6 is sleeved on the piston base 100 and abuts against the inner wall of the clamp 1. The sealing cavity is formed between the sealing ring 6 and the inner wall of the clamp 1. The sealing ring 6 not only performs sealing between the piston base 100 and the inner wall of the clamp 1 but also performs insulation and isolation functions between the piston base 100 and the clamp 1, making the sealing cavity become a closed cavity capable of bearing certain positive pressure and negative pressure.

[0037] The anode of the power supply 2 may be directly electrically connected to the piston base 100. However, by means of direct contact, it is difficult to guarantee the reliability and stability of an electrical connection. To solve this problem, as shown in FIG. 2, the piston manufacturing device further includes a fixed ring 7. The fixed ring 7 is a stainless steel ring. The fixed ring 7 is sleeved on the piston base 100 and abuts against a bottom surface of the sealing ring 6. After the sealing ring 6 is coated with vacuum grease and forms an interference fit with the fixed ring 7, each of connectors passes through the fixed ring 7 and the piston base 100. The connectors are M10 * 50 bolts. Six bolts are provided to guarantee the fixing effect between the fixed ring 7 and the clamp 1 and thereby guarantee the stability and reliability of clamping the piston base 100.

[0038] Optionally, the anode of the power supply 2 may be electrically connected to the piston base 100 through the connectors. The anode of the power supply 2 is electrically connected to the connectors. The connectors are connected to the fixed ring 7. The fixed ring 7 is connected to the piston base 100. Therefore, the anode of the power supply 2 is electrically connected to the piston base 100 so as to facilitate the installation between the anode of the power supply 2 and the piston base 100 and results in sound reliability.

[0039] Optionally, as shown in FIG. 2, the first reaction mechanism 3 includes a first reaction box 31 and a first valve 32. The first reaction box 31 is configured to accommodate a first electrolyte and communicate with the sealing cavity. The first valve 32 is configured to control the opening and closing of the first reaction box 31. The second reaction mechanism 4 includes a second reaction box 41 and a second valve 42. The second reaction box 41 is configured to accommodate a second electrolyte and communicate with the sealing cavity. The second valve 42 is configured to control the opening and closing of the second reaction box 41. The third reaction mechanism 5 includes a third reaction box 51 and a third valve 52. The third reaction box 51 is configured to accommodate sealant and communicate with the sealing cavity. The third valve 52 is configured to control the opening and closing of the third reaction box 51.

[0040] Optionally, the first reaction box 31, the second reaction box 41, and the third reaction box 51 are each disposed above the clamp 1. The first valve 32, the second valve 42, and the third valve 52 are disposed on the bottom of the first reaction box 31, the bottom of the second reaction box 41, and the bottom of the third reaction box 51 respectively. When each valve is opened, the liquid in a corresponding reaction box flows into the sealing cavity under the gravity of the liquid. When each valve is closed, the liquid in a corresponding reaction box stops entering the sealing cavity. The structure is simple by using this manner. However, the speed of a liquid flow is constant, making the liquid inlet speed relatively low and failing to implement liquid recovery.

[0041] To resolve the preceding problem, optionally, the piston manufacturing device further includes a hydraulic pump 8. An inlet of the hydraulic pump 8 communicates with the sealing cavity. An outlet of the hydraulic pump communicates with the first reaction box 31 and the second reaction box 41. The first valve 32 is disposed on a connection pipe between the hydraulic pump 8 and the first reaction box 31. The second valve 42 is disposed on a connection pipe between the hydraulic pump 8 and the second reaction box 41.

[0042] When the hydraulic pump 8 and the first valve 32 are opened, the hydraulic pump 8 drives the first electrolyte in the first reaction box 31 to be transmitted into the sealing cavity through the first joint. After the first electrolyte undergoes an electrochemical reaction with the top surface of the piston base 100 in the sealing cavity to form the porous function layer 101, the first electrolyte flows back into the first reaction box 31 through the inlet of the hydraulic pump 8 under the driving action of the hydraulic pump 8, thereby implementing the recycling of the first electrolyte.

[0043] When the hydraulic pump 8 and the second valve 42 are opened, the hydraulic pump 8 drives the second electrolyte in the second reaction box 41 to be transmitted into the sealing cavity through the first joint. After the second electrolyte undergoes an electrochemical reaction with the top surface of the porous function layer 101 in the sealing cavity to form the micropore filling layer 102, the second electrolyte flows back into the second reaction box 41 through the inlet of the hydraulic pump 8 under the driving action of the hydraulic pump 8, thereby implementing the recycling of the second electrolyte.

[0044] Optionally, the piston manufacturing device further includes a flow controller. The hydraulic pump 8 and the flow controller are configured to control the flow rate and water pressure of the first electrolyte and the flow rate and water pressure of the second electrolyte.

[0045] After the micropore filling layer 102 is manufactured by using the second electrolyte, the manufacturing process of the plasma oxide porous layer ends. To guarantee the bonding effect between the micropore filling layer 102 and the closing layer 103, the piston base 100 and the clamp 1 need to be dried. Optionally, as shown in FIG. 2, the piston manufacturing device further includes a three-way valve 9 and the pump 10. A first end of the three-way valve 9 communicates with the first reaction mechanism 3 and the second reaction mechanism 4 separately. A second end of the three-way valve 9 communicates with the sealing cavity and the third reaction mechanism 5. A third end of the three-way valve 9 communicates with the ambient atmosphere. The pump is disposed on a connection pipe between the hydraulic pump 8 and the clamp 1. The pump 10 is able to communicate with the sealing cavity so that ambient air enters the sealing cavity through the three-way valve 9 to blow and dry the piston base 100.

[0046] In the manufacturing process of the closing layer 103, the first reaction mechanism 3 and the second reaction mechanism 4 are no longer involved in a reaction. To guarantee the isolation effect between the clamp 1 and the first reaction mechanism 3 and between the clamp 1 and the second reaction mechanism 4, the piston manufacturing device further includes a first vacuum valve 11 and a second vacuum valve 12. The first vacuum valve 11 and the second vacuum valve 12 are disposed on two sides of the pump 10. The first vacuum valve 11 is disposed between the hydraulic pump 8 and the pump 10. The second vacuum valve 12 is disposed between the pump 10 and the clamp 1.

[0047] When drying needs to be performed, the second vacuum valve 12 and the three-way valve 9 are opened and the first vacuum valve 11 is closed so as to cut off the communication with the first reaction box 31 and the second reaction box 41. In this case, the first reaction mechanism 3 and the second reaction mechanism 4 may also be disassembled so that only the pump 10 and the clamp 1 are in operation. The pump 10 starts to operate. The three-way valve 9 is opened. The pump 10 extracts the air in the sealing cavity so that the ambient air enters through the three-way valve 9, then enters the clamp 1 through the first joint, and flows out from the second joint. In this case, the first joint performs an air inlet function, and the second joint performs an air outlet function. The inner wall of the clamp 1 and the piston base 100 are dried through the circulation and flow of air.

[0048] Optionally, the pump serves as a driving source of drying and may also serve as a driving source of the procedure of manufacturing the closing layer 103. Exemplarily, after drying is performed, the sealant is added to the third reaction box 51. Then the three-way valve 9, the first vacuum valve 11, and the third valve 52 are closed. The second vacuum valve 12 is opened. The pump 10 is opened so that the pump 10 provides a vacuum for the sealing cavity. After the air pressure in the sealing cavity reaches a preset vacuum degree, the pump 10 and the second vacuum valve 12 are closed, and the third valve 52 is opened. Under the action of the negative pressure in the sealing cavity, the sealant in the third reaction box 51 flows towards the clamp 1 through the third valve 52 and is sprayed to the top of the piston base 100 through the first joint so that the closing layer 103 is sprayed onto on the micropore filling layer 102. After a period of reaction time, for example, 1 min, the three-way valve 9 is opened for air bleeding. The piston based 100 for which pore sealing has been performed is unloaded and placed in a drying box for drying. Therefore, pore sealing is completed.

[0049] In the existing manufacturing of a plasma oxide coating, the concentration may be increased by adding a solute so as to implement a traditional electrolyte adjustment. However, when the concentration needs to be reduced or when solutions with different ratios are provided in different growth stages of the plasma oxide coating, a reaction needs to be interrupted and an electrolyte is re-prepared, increasing the manufacturing time and cost.

[0050] To solve this problem, this embodiment further provides a piston manufacturing method for manufacturing a piston by using the preceding piston manufacturing device. The piston manufacturing method includes the following steps: The clamp 1 is used for sealingly clamping the piston base 100, and the sealing cavity is formed between the piston base 100 and the clamp 1; the anode of the power supply 2 is electrically connected to the piston base 100, and the cathode of the power supply 2 is electrically connected to the clamp 1; the first reaction mechanism 3 is opened and the second reaction mechanism 4 and the third reaction mechanism 5 are closed so that the first reaction mechanism 3 communicates with the sealing cavity, and the porous function layer 101 is formed on the top surface of the piston base 100 by using an electrochemical manner; the second reaction mechanism 4 is opened and the first reaction mechanism 3 and the third reaction mechanism 5 are closed so that the second reaction mechanism 4 communicates with the sealing cavity, and the micropore filling layer 102 is formed on the top surface of the porous function layer 101 by using the electrochemical manner; and the third reaction mechanism 5 is opened and the first reaction mechanism 3 and the second reaction mechanism 4 are closed so that the third reaction mechanism 5 communicates with the sealing cavity, and the closing layer 103 covering the top surface of the micropore filling layer 102 is formed.

[0051] For the piston manufacturing method provided in this embodiment, the anode of the power supply 2 is electrically connected to the piston base 100 and the cathode of the power supply 2 is electrically connected to the clamp 1 so as to be used in electrochemical reactions for generating the porous function layer 101 and the micropore filling layer 102. The arrangement in which only the first reaction mechanism 3 is opened is used for manufacturing the porous function layer 101 in the sealing cavity. The arrangement in which only the second reaction mechanism 4 is opened is used for manufacturing the micropore filling layer 102 in the sealing cavity. The arrangement in which only the third reaction mechanism 5 is opened is used for manufacturing the micropore closing layer 103 in the sealing cavity. The separate-control arrangement in which the first reaction mechanism 3, the second reaction mechanism 4, and the third reaction mechanism 5 are independent of each other enables the free combination and recycling of various electrolytes to be implemented without interrupting a test, resulting in an independent adjustment and sound flexibility. Moreover, the clamp 1 only needs to clamp and fix the piston base 100 once so that installation and disassembly do not need to be performed for each reaction, simplifying the process and saving the manufacturing cost. Additionally, each procedure is performed in the sealing cavity, avoiding coating pollution.

[0052] Optionally, to guarantee the effect of manufacturing the coating on the top surface of the piston base 100, before the clamp 1 clamps the piston base 100, the top surface of the piston base 100 is preprocessed. Before the plasma oxide coating is manufactured, the top of the piston base 100 needs to be preprocessed with a main object of removing grease, dirt, and scratches on the surface of the piston base 100.

[0053] Exemplarily, the preprocessing includes the following steps: The piston base 100 is degreased so as to remove the grease and dirt on the top of the piston base 100; the top surface of the piston base 100 is matted with 1500-grit sandpaper to form a micro-gully structure on the top surface so as to increase the bonding area of the coating and the piston base 100 and enhance the bonding force; and ultrasonic cleaning, washing, and air drying are performed to obtain the clean and relatively rough surface.

[0054] The preprocessed piston base 100 is placed in the clamp 1 to be clamped and fixed. Then the anode of the power supply 2 and the cathode of the power supply 2 are electrically connected to the piston base 100 and the clamp 1 respectively. The first reaction mechanism 3 is able to transmit the first electrolyte to the sealing cavity. Sodium silicate nonahydrate (10 g/L-25 g/L), sodium hydroxide (0.5 g/L-3 g/L), ethylenediaminetetraacetic acid disodium salt (0.5 g/L-3 g/L), sodium triphosphate (1 g/L-5 g/L), and sodium tungstate (0.5 g/L-3g/L) serve as electrolytic solutes. Deionized water serves as a solvent. In this case, the first electrolyte with a preset concentration is prepared.

[0055] The piston base 100 serves as an anode to be clamped on the clamp 1 that is insulated from the clamp 1. The clamp 1 is connected to the cathode of the power supply 2. The power supply 2 is output in a constant current pulse mode. In this process, the current density is set to 8 A/dm^2-20 A/dm^2. The ratio of negative currents to positive currents is 0.9-1.3. The duty ratio of negative pulses to positive pulses is 30%-65%. The range of pulse frequency is 800 Hz-1600 Hz. In the first 10 min, a low current of 8 A/dm^2-12 A/dm^2 is used constantly. After 10 min, the current increases progressively by 20% every 2 min till an arc strike. After arc light appears in the preceding steps, the current is gradually reduced to 10 A/dm^2-15 A/dm^2. Electrolyte temperature is controlled at 20°C-25°C. Discharge is kept for 35 min-55 min after the voltage enters a stable region.

[0056] In the manufacturing process of the porous function layer 101 in this embodiment, optionally, a positive current of the power supply 2 is set to 3 A. A negative current of the power supply 2 is 6.8 A. The frequency of power supply 2 is 1000 Hz. The duty ratio of positive pulses to negative pulses is 60: 40. After 20 min, the positive current is increased to 3.6 A for 2 min, to 4.3 A for 2 min, and 5.2 A for 2 min and is increased by 20% progressively till the arc strike. After the arc strike, the current is adjusted to 6 A. Constant temperature is kept, and discharge is kept continuously for 45 min.

[0057] After the manufacturing of the porous function layer 101 is completed by using the first electrolyte, the second reaction mechanism 4 is able to transmit the second electrolyte to the sealing cavity. Sodium silicate nonahydrate (10 g/L-25 g/L), sodium hydroxide (0.5 g/L-3 g/L), ethylenediaminetetraacetic acid disodium salt (0.5 g/L-3 g/L), sodium triphosphate (1 g/L-5 g/L), sodium tungstate (0.5 g/L-3g/L), triethanolamine (1 ml/L-3.5 ml/L), and Nano ZrO_2 (5 g/L-12 g/L) serve as electrolytic solutes. The constant current pulse mode is used for output. In this process, the current density is set to 14 A/dm^2-18 A/dm^2. The ratio of negative currents to positive currents is 0.9-1.3. The duty ratio of negative pulses to positive pulses is 50%-65%. The range of pulse frequency is 1000 Hz-16500 Hz. The time is 10 min-20 min.

[0058] In the manufacturing process of the micropore filling layer 102 in this embodiment, a positive current of the power supply 2 is set to 8 A. A negative current of the power supply 2 is 9 A. The frequency of power supply 2 is 1200 Hz. The duty ratio of positive pulses to negative pulses is 50: 50. Discharge is kept for 15 min.

[0059] The porous function layer 101 and the micropore filling layer 102 that have been manufactured have the function of thermal insulation, effectively hindering the heat loss in the combustion chamber. Under the condition of a thermal fatigue test, the piston has a longer service life than an ordinary aluminum piston. Since the porous function layer 101 and the micropore filling layer 102 each have a porous structure with a high porosity, enabling the temperature of a coating wall to change rapidly and avoiding air-inlet heating. The piston base 100 avoids intense heat exchange, improving the efficiency of converting heat into useful work. Fuel consumption reduces by about 0.3%.

[0060] The electrolytic solute of the second electrolyte contains nano ZrO_2. ZrO_2 nanoparticles are used as filling materials. However, in the manufacturing process of plasma oxide, high-concentration ZrO_2 may lead to an increase in the arc strike voltage and the increase of energy applied to the surface per unit time. When the coating grows to a certain thickness, the breakdown difficulty increases, easily causing continuous discharge at only a few weak places, reducing the overall thickness of the coating, and limiting the thermal insulation performance. However, the sealing effect of low-concentration ZrO_2 is poor and has little contribution to reducing thermal conductivity.

[0061] Because of the preceding phenomenon, this embodiment employs the first reaction mechanism 3 and the second reaction mechanism 4 which are independent of each other. The first valve 32 is used for controlling the flow and switch of the first electrolyte in the first reaction box 31. The first electrolyte is mainly provided for manufacturing the porous function layer 101 with a larger thickness. The thickness of the loose porous function layer 101 is about 90 μm-110 μm. The second valve 42 is used for controlling the flow and switch of the second electrolyte in the second reaction box 41. The second electrolyte is an electrolyte containing high-concentration ZrO_2 and is provided for manufacturing the microporous filling layer 102. The microporous filling layer 102 is able to reduce capacitance and seal pores in the porous function layer 101 to a certain extent.

[0062] After the manufacturing of the micropore filling layer 102 is completed and before the closing layer 103 is formed, the power supply 2, the first reaction mechanism 3, the second reaction mechanism 4, and the third reaction mechanism 5 are closed and the three-way valve 9 and the pump 10 are opened so that ambient air enters the sealing cavity through the three-way valve 9 to blow and dry the piston base 100 and the clamp 1. Optionally, the time for blowing and drying is 15 min-20 min. Drying is also completed in the sealing cavity. The clamp 1 does not need to be disassembled in the entire process, avoiding coating pollution and saving the time cost.

[0063] After drying, the third reaction mechanism 5 is able to transmit the sealant to the sealing cavity. The sealant is polysilazane. After the sealant of 50 ml is added to the third reaction box 51, the three-way valve 9, the third valve 52, and the first vacuum valve 11 are closed and the pump 10 is opened so that a vacuum of 0.08 Mpa-0.1 Mpa is kept in the sealing cavity. Then the second vacuum valve 12 is closed and the third valve 52 is opened. The sealant in the third reaction box 51 is absorbed into the sealing cavity by the negative pressure in the sealing cavity. The sealant is sprayed onto the top surface of the micropore filling layer 102 through the first joint so as to implement the pore sealing of the micropore filling layer 102. After a period of reaction time, for example, 1 min, the three-way valve 9 is opened for air bleeding. The piston based 100 for which pore sealing has been performed is unloaded and placed in the drying box for drying. Therefore, pore sealing is completed.

[0064] In the pore sealing process, the independent first valve 32 and the independent second valve 42 control the first reaction box 31 and the second reaction box 41 respectively so as to implement the negative pressure vacuum pore sealing and guarantee the recycling of the first electrolyte and the recycling of the second electrolyte. Additionally, the manufacturing of the porous function layer 101, the manufacturing of the micropore filling layer 102, and the coating and drying of the closing layer 103 may be completed in the same station of the sealing cavity, thereby avoiding coating pollution, simplifying the processing process, and shortening the manufacturing period.

[0065] As shown in FIG. 3, the piston manufacturing method provided in this embodiment includes the steps below.

[0066] In S1, the top surface of the piston base 100 is preprocessed.

[0067] In S2, the first electrolyte is prepared and placed in the first reaction box 31, and the second electrolyte is prepared and placed in the second reaction box 41.

[0068] In S3, the preprocessed piston base 100 is placed in the clamp 1 to be clamped and fixed, and the anode of the power supply 2 and the cathode of the power supply 2 are electrically connected to the piston base 100 and the clamp 1 respectively.

[0069] In S4, the power supply 2, the hydraulic pump 8, the first valve 32, and the three-way valve 9 are opened, and the first electrolyte is transmitted to the sealing cavity to complete the manufacturing of the porous function layer 101.

[0070] In S5, the power supply 2, the hydraulic pump 8, the second valve 42, and the three-way valve 9 are opened, and the second electrolyte is transmitted to the sealing cavity to complete the manufacturing of the micropore filling layer 102.

[0071] In S6, the power supply 2, the hydraulic pump

8, the first valve 32, the second valve 42, the third valve 52, and the first vacuum valve 11 are closed and the three-way valve 9, the pump 10, and the second vacuum valve 12 are opened so that the sealing cavity is blown and dried.

[0072] In S7, the sealant is placed in the third reaction box 51, the pump 10 and the second vacuum valve 12 are closed, the third valve 52 is opened, the sealant is sprayed onto the top surface of the piston base 100 by the negative pressure in the sealing cavity, and preset time is maintained.

[0073] In S8, the three-way valve 9 is opened to air-bleed the sealing cavity, and the piston base 100 is disassembled and placed in the air to be dried.

[0074] The present application has the beneficial effects below.

[0075] For the piston provided in the present application, the porous function layer 101 is disposed in the top surface of the piston base 100. The micropore filling layer 102 is disposed in the top surface of the porous function layer 101. The pores in the micropore filling layer 102 and the pores in the porous function layer 101 form channels. The channels are used for storing air and play the function of thermal insulation. The diameter of each of pores in the micropore filling layer 102 is smaller than the diameter of each of pores in the porous function layer 101. In this case, the micropore filling layer 102 performs a transition between the porous function layer 101 and the closing layer 103 and fills the porous function layer 101 to a certain extent. The closing layer 103 is disposed on the top surface of the micropore filling layer 102 and configured to block the pores in the micropore filling layer 102. Accordingly, the closing layer 103 performs the function of blocking, preventing a high-temperature gas and a corrosive medium from entering the pores of the porous function layer 101 and the pores of the micropore filling layer 102 to oxide the porous function layer 101 and the micropore filling layer 102 at a high temperature and corrode the porous function layer 101 and the micropore filling layer 102, thereby protecting the piston base 100, and improving the high-temperature resistance and corrosion resistance of the piston.

[0076] Additionally, with the coordination of the porous function layer 101 and the micropore filling layer 102, air filling may be formed in the pores of the porous function layer 101 and the pores of the micropore filling layer 102, effectively reducing the volumetric heat capacity of the piston coating, better guaranteeing the performance of thermal insulation and protection, and implementing the protection performance of controlling combustion temperature. In this case, the piston is easily heated. The air inlet temperature of cold air entering a combustion chamber is low, avoiding air-inlet heating, thereby improving the efficiency of converting heat into useful work, and effectively reducing fuel consumption.

[0077] For the piston manufacturing device provided in the present application, the clamp 1 performs a fixing effect on the piston base 100. The top of the piston base 100 sealingly extends into the clamp 1 to form the sealing cavity with the inner wall of the clamp 1. The sealing cavity provides a reaction environment for manufacturing a coating on the top surface of the piston base 100. The first reaction mechanism 3 communicates with the sealing cavity and is configured to manufacture the porous function layer 100 on the top surface of the piston base 101. The second reaction mechanism 4 communicates with the sealing cavity and is configured to manufacture the micropore filling layer 102 on the top surface of the porous function layer 101. The third reaction mechanism 5 communicates with the sealing cavity and is configured to manufacture the closing layer 103 on the top surface of the micropore filling layer 102. With the adoption of this structure, the manufacturing process of the porous function layer 101, the manufacturing process of the micropore filling layer 102, and the manufacturing process of the closing layer 103 are completed in the sealing cavity formed by the specialized clamp 1 and the top of the piston base 100 with no need for installing and disassembling each reaction mechanism, saving the time cost and avoiding the secondary pollution of each coating.

[0078] For the piston manufacturing method provided in the present application, the anode of the power supply 2 is electrically connected to the piston base 100 and the cathode of the power supply 2 is electrically connected to the clamp 1 so as to be used in electrochemical reactions for generating the porous function layer 101 and the micropore filling layer 102. The arrangement in which only the first reaction mechanism 3 is opened is used for manufacturing the porous function layer 101 in the sealing cavity. The arrangement in which only the second reaction mechanism 4 is opened is used for manufacturing the micropore filling layer 102 in the sealing cavity. The arrangement in which only the third reaction mechanism 5 is opened is used for manufacturing the micropore closing layer 103 in the sealing cavity. The separate-control arrangement in which the first reaction mechanism 3, the second reaction mechanism 4, and the third reaction mechanism 5 are independent of each other enables the free combination and recycling of various electrolytes to be implemented without interrupting a test, resulting in an independent adjustment and sound flexibility. Moreover, the clamp 1 only needs to clamp and fix the piston base 100 once so that installation and disassembly do not need to be performed for each reaction, simplifying the process and saving the manufacturing cost. Additionally, each procedure is performed in the sealing cavity, avoiding coating pollution.

[0079] In the description of the present application, it is to be understood that the orientation or position relationships indicated by terms "above", "below", "right" and the like are the orientation or position relationships shown in the drawings, merely for ease of description and simplifying operations, and these relationships do not indicate or imply that the referred device or component has a specific orientation and is constructed and operated in a specific orientation, and thus it is not to be construed as a limitation to the present application. In addition, the terms "first" and "second" are used only to distinguish between descriptions and have no special meaning.

[0080] In the description of the specification, the description of reference terms "an embodiment" or "example" means that specific characteristics, structures, materials, or features described in connection with the embodiment or example are included in at least one embodiment or example of the present application. In the specification, the illustrative description of the preceding terms does not necessarily refer to the same embodiment or example.

Claims

1. A piston, comprising:

    a piston base (100);
    a porous function layer (101), disposed on a top surface of the piston base (100);
    a micropore filling layer (102), disposed on a top surface of the porous function layer (101), wherein a diameter of each of pores in the micropore filling layer (102) is smaller than a diameter of each of pores in the porous function layer (101); and
    a closing layer (103), disposed on a top surface of the micropore filling layer (102) and configured to partially block the pores in the micropore filling layer (102).

2. The piston according to claim 1, wherein in a direction away from the porous function layer (101), at least one parameter of porosities of the pores in the micropore filling layer (102) and diameters of the pores in the micropore filling layer (102) is in descending order.

3. A piston manufacturing device, configured to manufacture the piston according to any one of claims 1 to 2, comprising:

    a clamp (1), configured to clamp a piston base (100), wherein a top of the piston base (100) is sealingly extends into the clamp (1) and forms a sealing cavity with an inner wall of the clamp (1);
    a power supply (2), wherein an anode of the power supply (2) is electrically connected to the piston base (100), and a cathode of the power supply (2) is electrically connected to the clamp (1);
    a first reaction mechanism (3), selectively communicating with the sealing cavity so as to form a porous function layer (101) on a top surface of the piston base (100);
    a second reaction mechanism (4), selectively communicating with the sealing cavity so as to form a micropore filling layer (102) on a top surface of the porous function layer (101); and
    a third reaction mechanism (5), selectively communicating with the sealing cavity so as to form a closing layer (103) on a top surface of the micropore filling layer (102).

4. The piston manufacturing device according to claim 3, further comprising:

    a three-way valve (9), wherein a first end of the three-way valve (9) communicates with the first reaction mechanism (3) and the second reaction mechanism (4) separately, a second end of the three-way valve (9) communicates with the sealing cavity and the third reaction mechanism (5), and a third end of the three-way valve (9) communicates with ambient atmosphere; and
    a pump (10) able to communicate with the sealing cavity so that ambient air enters the sealing cavity through the three-way valve (9) to blow and dry the piston base (100).

5. The piston manufacturing device according to claim 3, further comprising a sealing ring (6), wherein the sealing ring (6) is sleeved on the piston base (100) and abuts against the inner wall of the clamp (1), and the sealing cavity is formed between the sealing ring (6), and the inner wall of the clamp (1).

6. The piston manufacturing device according to claim 5, further comprising a fixed ring (7) and connectors, wherein the fixed ring (7) is sleeved on the piston base (100) and abuts against a bottom surface of the sealing ring (6), and each of the connectors passes through the fixed ring (7) and the piston base (100).

7. A piston manufacturing method, for manufacturing a piston by using the piston manufacturing device according to any one of claims 3 to 6, comprising:

    using a clamp (1) for sealingly clamping a piston base (100), and forming a sealing cavity between the piston base (100) and an inner wall of the clamp (1);
    electrically connecting an anode of a power supply (2) to the piston base (100), and electrically connecting a cathode of the power supply (2) to the clamp (1);
    opening a first reaction mechanism (3) and closing a second reaction mechanism (4) and a third reaction mechanism (5) so that the first reaction mechanism (3) communicates with the sealing cavity; and forming, by using an electrochemical manner, a porous function layer (101) on a top surface of the piston base (100);

opening the second reaction mechanism (4) and closing the first reaction mechanism (3) and the third reaction mechanism (5) so that the second reaction mechanism (4) communicates with the sealing cavity; and forming, by using the electrochemical manner, a micropore filling layer (102) on a top surface of the porous function layer (101); and
opening the third reaction mechanism (5) and closing the first reaction mechanism (3) and the second reaction mechanism (4) so that the third reaction mechanism (5) communicates with the sealing cavity; and forming a closing layer (103) covering a top surface of the micropore filling layer (102).

8. The piston manufacturing method according to claim 7, before forming the closing layer (103), further comprising closing the power supply (2), the first reaction mechanism (3), the second reaction mechanism (4), and the third reaction mechanism (5) and opening a three-way valve (9) and a pump (10) so that ambient air enters the sealing cavity through the three-way valve (9) to blow and dry the piston base (100) and the clamp (1).

9. The piston manufacturing method according to claim 7, wherein the first reaction mechanism (3) is configured to transmit a first electrolyte to the sealing cavity, the second reaction mechanism (4) is configured to transmit a second electrolyte to the sealing cavity, and the third reaction mechanism (5) is configured to transmit sealant to the sealing cavity.

10. The piston manufacturing method according to claim 7, before using the clamp (1) for sealingly clamping the piston base (100), further comprising preprocessing the top surface of the piston base (100).

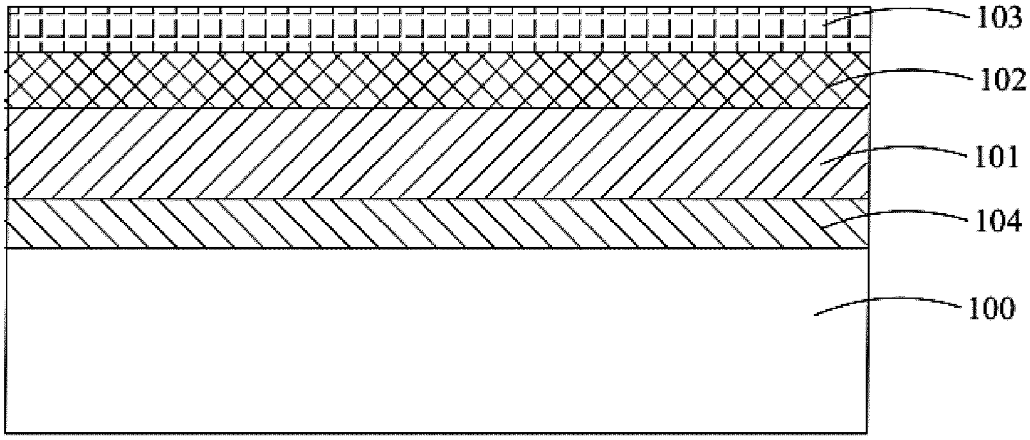

FIG. 1

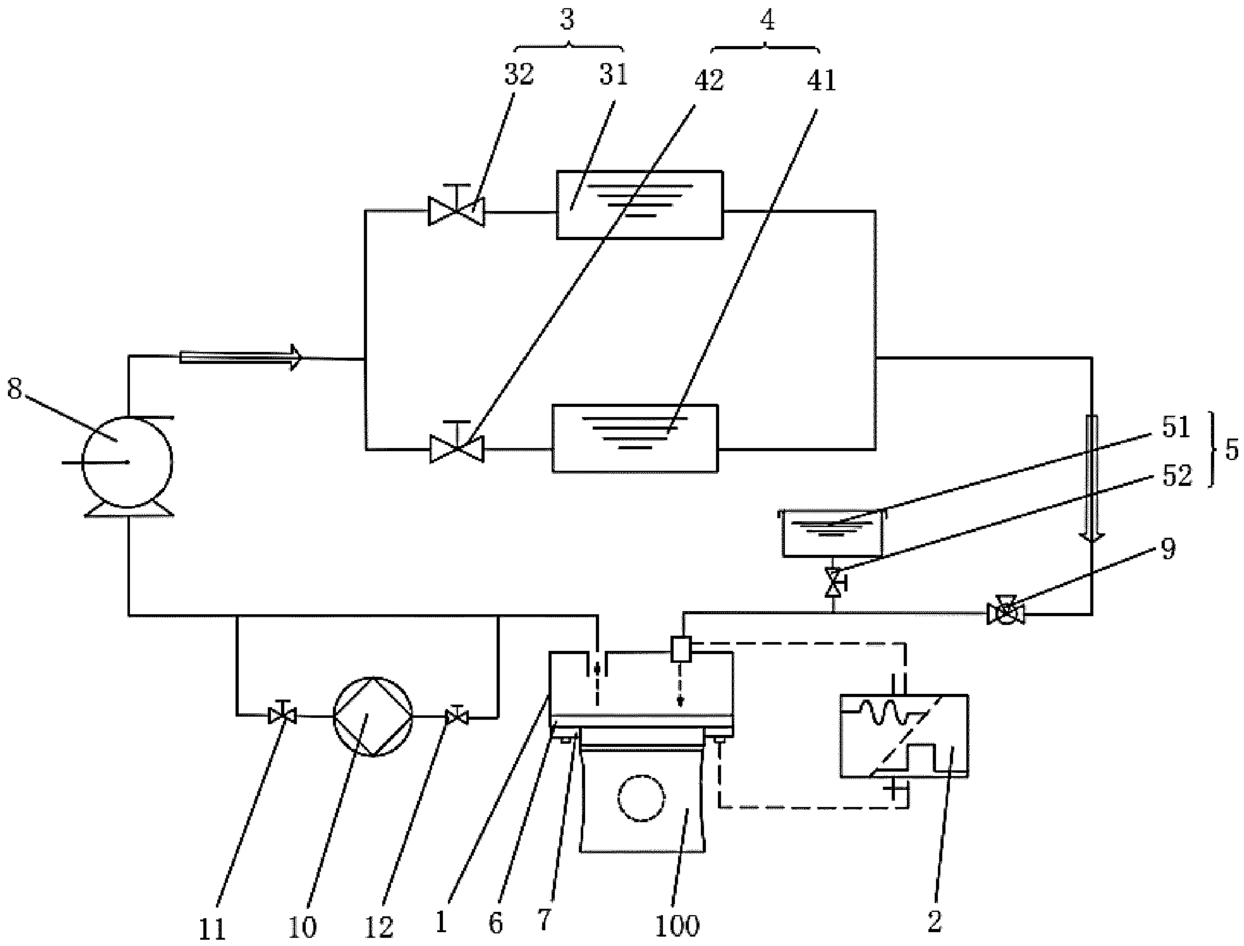

FIG. 2

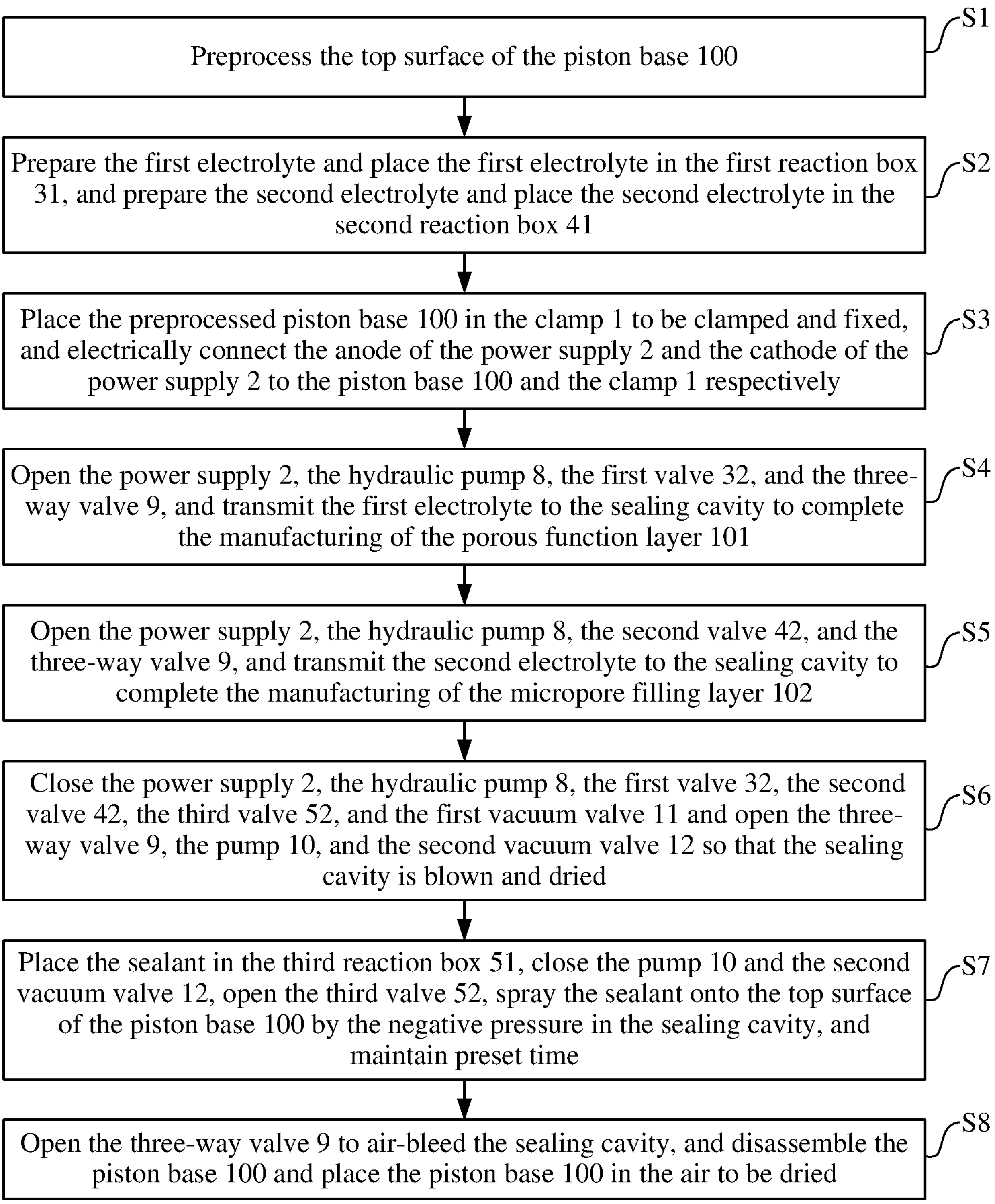
S1
Preprocess the top surface of the piston base 100
S2
Prepare the first electrolyte and place the first electrolyte in the first reaction box 31, and prepare the second electrolyte and place the second electrolyte in the second reaction box 41
S3
Place the preprocessed piston base 100 in the clamp 1 to be clamped and fixed, and electrically connect the anode of the power supply 2 and the cathode of the power supply 2 to the piston base 100 and the clamp 1 respectively
S4
Open the power supply 2, the hydraulic pump 8, the first valve 32, and the three-way valve 9, and transmit the first electrolyte to the sealing cavity to complete the manufacturing of the porous function layer 101
S5
Open the power supply 2, the hydraulic pump 8, the second valve 42, and the three-way valve 9, and transmit the second electrolyte to the sealing cavity to complete the manufacturing of the micropore filling layer 102
S6
Close the power supply 2, the hydraulic pump 8, the first valve 32, the second valve 42, the third valve 52, and the first vacuum valve 11 and open the three-way valve 9, the pump 10, and the second vacuum valve 12 so that the sealing cavity is blown and dried
S7
Place the sealant in the third reaction box 51, close the pump 10 and the second vacuum valve 12, open the third valve 52, spray the sealant onto the top surface of the piston base 100 by the negative pressure in the sealing cavity, and maintain preset time
S8
Open the three-way valve 9 to air-bleed the sealing cavity, and disassemble the piston base 100 and place the piston base 100 in the air to be dried

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No. **PCT/CN2020/134196**

A. CLASSIFICATION OF SUBJECT MATTER

F02F 3/00(2006.01)i; F02F 3/10(2006.01)i; C25D 7/04(2006.01)i; C25D 15/00(2006.01)i; C25D 3/02(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02F C25D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNKI, CNPAT, WPI, EPODOC: 潍柴动力, 活塞, 多孔, 微孔, 封闭, 密封, 孔, 隔热, 绝热, 层, 电, 三通, 泵, 阀, 夹具, piston, porous, multi+, micro, hole?, micropore?, insulat+, heat+, thermal, baffl+, power, electrode? , holder? , grip+, valve?

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 111535935 A (WEICHAI POWER CO., LTD.) 14 August 2020 (2020-08-14) description, paragraphs [0027]-[0064], and figures 1-3	1-10
X	CN 105339531 A (SUZUKI MOTOR CORPORATION) 17 February 2016 (2016-02-17) description, paragraphs [0008]-[0069], and figures 1-3	1
Y	CN 105339531 A (SUZUKI MOTOR CORPORATION) 17 February 2016 (2016-02-17) description, paragraphs [0008]-[0069], and figures 1-3	2-9
Y	CN 107313095 A (CHONGQING XIECHENG AUTO PARTS CO., LTD.) 03 November 2017 (2017-11-03) description, paragraphs [0005]-[0033], and figures 1-4	2-9
A	CN 105452503 A (TOYOTA JIDOSHA KABUSHIKI KAISHA) 30 March 2016 (2016-03-30) entire document	1-10
A	US 2007218303 A1 (NISSAN MOTOR CO., LTD. et al.) 20 September 2007 (2007-09-20) entire document	1-10
A	JP 2017061722 A (AISIN SEIKI K. K.) 30 March 2017 (2017-03-30) entire document	1-10

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 March 2021	**26 March 2021**

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Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
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International application No.
PCT/CN2020/134196

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				JP	2018204611	A	27 December 2018
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				WO	2018180180	A1	04 October 2018
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				JP	2016199030	A	01 December 2016
				US	2018094603	A1	05 April 2018
				WO	2016163244	A1	13 October 2016

Form PCT/ISA/210 (patent family annex) (January 2015)