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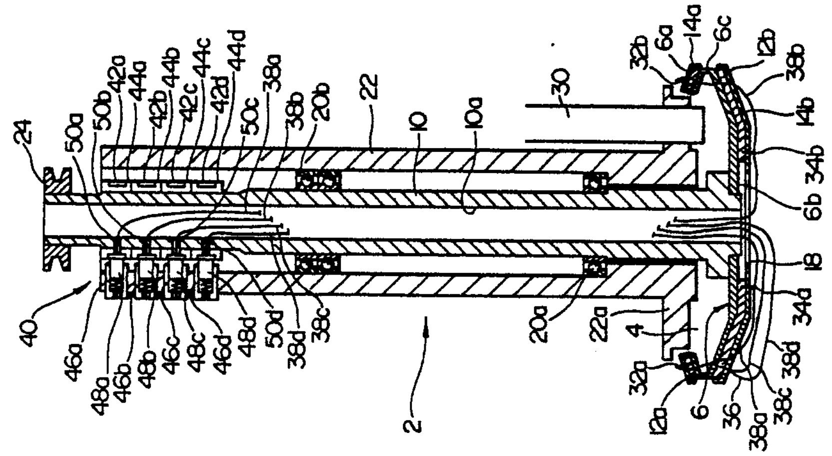
(54) Centrifugal spinning apparatus for pitch fibers.

(57) A centrifugal spinning apparatus is disclosed which includes a spinner disc (6) having a top wall (6a), a bottom wall (6b) and a side wall (6c) connecting the top wall and the bottom wall to each other, a plurality of spinning nozzles being formed in the side wall. The spinner disc is rotated at a high speed to thereby spin a molten pitch, fed into the spinner disc, into pitch fibers through the spinning nozzles. Heating members (l2a), l2b) are provided to the spinner disc (6). The heating members are made of electrically conductive heating material.

FIG. 1



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CENTRIFUGAL SPINNING APPARATUS FOR PITCH FIBERS

BACKGROUND OF THE INVENTION

The present invention relates to a centrifugal spinning apparatus for pitch fiber, and, more particularly, to a pitch fiber centrifugal apparatus in which an isotropic pitch or a mesophase pitch made from a starting material such as a petroleum pitch and coal pitch is used as a raw material, and the material is heated and molten for centrifugal spinning, thereby producing a pitch fiber to be used as a preformed material for a carbon fiber.

In general, a pitch fiber centrifugal spinning apparatus comprises a top wall, a bottom wall and a side wall for connecting the top wall and the bottom wall to each other, and the side wall is provided with a spinner disc having therein a plurality of spinning nozzles. The spinner disc is rotated at a high speed so that a molten pitch fed into the spinner disc is spun into pitch fibers through the spinning nozzles. Namely, the molten pitch is fed out of the spinning nozzles by the centrifugal force generated by the high speed rotation of the spinner disc, and the fed molten pitch is elongated by an air friction generated around the spinner disc due to the high speed rotation thereof, so that the molten pitch is formed into pitch fibers.

In such a centrifugal spinning apparatus, upon the centrifugal spinning of the molten pitch, in order to well form the molten pitch into fibers and to obtain carbon fibers having a desired structure in cross-section, it has been proposed to use some heating means for the centrifugal spinning apparatus. For instance, such proposal is shown in Japanese Patent Unexamined Publication Nos. l544l6/82 and 203l05/83.

The above-described Japanese publication No. l544l6/82 disclosed an apparatus in which, in the case where a molten pitch adjusted to have a temperature of 330 to 450°C and a viscosity of l0 to l00 poises is spun, a centrifugal rotational spinning is carried out while applying thereto a blow of air, kept at a temperature of 230 to 400°C, in the pitch fiber spinning direction.

The Japanese publication No. 203l05/83 discloses an apparatus in which heaters are provided to upper and lower surfaces of the rotary spinning disc in spaced and confronted relation, and spinning nozzles are formed in the bottom and/or top portion of the spinning disc facing the heaters.

The heating means shown in the Japanese Patent Unexamined Publication Nos. l544l6/82 and 203l05/83 are constructed so that a high temperature gas heated by a heat source located apart from the spinner disc is blown to the spinner disc, or that the spinner disc is heated by the heaters used as heat sources spaced apart from the spinner disc. Namely, the heating means of these publications are of the indirect heating type. In such an indirect heating system, a temperature difference between the heat source and the molten pitch fed out of the spinning nozzles of the spinner disc tends to be considerable. For this reason, it would be difficult to exactly control the molten pitch discharge temperature in accordance with the indirect heating system. It would be more difficult to control the temperature in the case where the discharge amount of the molten pitch is increased. If the discharge temperature of the molten pitch would not exactly be controlled, the discharge amount of the molten pitch would be varied so that the pitch fibers would have different fibrous diameters. At the same time, it would be difficult to form the molten pitch into fibers well and to control the cross-sectional structure of the carbon fibers in a desired manner, which will lead to the degradation in quality of the products.

In the indirect heating system, when the discharge amount of the molten pitch is increased, the temperature of the spinning nozzles through which the molten pitch is discharged is liable to be lower than a predetermined temperature. In order to avoid this, it is necessary to keep the temperature of the molten pitch, to be fed into the spinner disc, at a higher temperature than an optimum discharge temperature corresponding to the above-described predetermined temperature. However, in this case, undesirable phenomena in spinning, such as foaming, phase separation, and polymerization of the molten pitch would be caused. These phenomena cause a disadvantage that the fibers are braked or snapped upon the pitch fiber spinning, and it would be difficult to control the cross-sectional structure of the carbon fibers, which leads to the degradation in quality.

Furthermore, the above-described conventional heating means would tend to make the apparatus as a whole large in size because the heating means further need means for ventilating the high temperature gas in the spinning direction or the heaters are arranged in spaced and confronted relation with the spinner disc. Thus, the conventional heating means would involve a structural problem that the equipment space is increased.

On the other side, the isotropic pitch made of a starting material of petroleum or coal pitches has a remarkable viscosity change in accordance with the temperature change, and tends to rapidly increase its viscosity when the temperature is lowered. Such is the case in the mesophase pitches. Therefore, in the case where these pitches are used as raw material and are spun in the above-described conventional centrifugal spinning apparatus, the molten pitch that has been fed from the spinning nozzles formed in an outer periphery of the spinner disc side wall is abruptly cooled to have a high viscosity and is often solidified without being subjected to a sufficient elongation by the air friction. For this reason, the pitch would be formed into a bead-like mass (referred to as a shot), and even if the pitch is under the fibrous state, the pitch would have a large diameter. It is difficult to say that this pitch is the "fiber".

Accordingly, an object of the present invention is to provide a pitch fiber centrifugal spinning apparatus which is capable of exactly controlling the temperature of the molten pitch within the spinner disc, more particularly, the molten pitch to be fed out of the spinning nozzles, thereby producing carbon fibers having a high quality, and does not require a large space where the apparatus is arranged.

Also, another object of the present invention is to provide a pitch fiber centrifugal spinning apparatus in which a rapid decrease in temperature of the molten pitch that has been just fed out of the spinning nozzles formed in the outer periphery of the spinner disc side wall is prevented while subjecting the molten pitch to a sufficient elongation, to thereby produce pitch fibers having a sufficiently small diameter and a high quality.

SUMMARY OF THE INVENTION

In order to attain these and other objects, according to the present invention, there is provided a centrifugal spinning apparatus including a spinner disc having a top wall, a bottom wall and a side wall connecting the top wall and the bottom wall to each other, a plurality of spinning nozzles being formed in the side wall, the spinner disc being rotated at a high speed to thereby spin a molten pitch, fed into the spinner disc, into pitch fibers through the spinning nozzles, the centrifugal spinning apparatus comprising an improvement in which a heating means is provided to the spinner disc, the heating means being made of electrically conductive heating material.

More preferably, the spinning apparatus according to the present invention comprises a hollow fixed shaft coaxially disposed above the spinner disc; a hollow rotary shaft coaxially disposed at a central portion of the spinner disc and rotatably supported to the hollow fixed shaft for rotating the spinner disc at the high speed; and electric power supply means electrically connected to the heating means, for supplying an electric power to the heating means to heat the heating means, wherein the electric power supply means comprises electric wiring means electrically connected to the heating means and extending upwardly through a central hole of the hollow rotary shaft, and a rotary power supply mechanism electrically connected to the electric wiring means and enabling to supply the electric power to the electric wiring means from the outside while rotating the electric wiring means together with the spinner disc and the hollow rotary shaft.

More preferably, the centrifugal spinning apparatus according to the present invention, heat radiative surfaces are provided on the side wall of the spinner disc, the heat radiative surfaces extending in a circumferential direction of the side wall and being positioned to face to each other to allow the molten pitch, discharged through the spinning nozzles, to pass between the heat radiative surfaces.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. I is a longitudinal sectional view showing a pitch fiber centrifugal spinning apparatus in accordance with a first embodiment of the invention;

Fig. 2 is an enlarged view of a left half portion of a spinner disc in the apparatus shown in Fig. I

Fig. 3 is a bottom view of the spinner disc shown in Fig. I;

Fig. 4 is a schematic view showing a whole system composed of a melting section and a spinning section, including the centrifugal spinning apparatus shown in Fig. I;

Fig. 5 is a longitudinal sectional view of a centrifugal spinning apparatus in accordance with a second embodiment of the invention;

Fig. 6 is an enlarged view of a left half portion of the spinner disc in the apparatus shown in Fig. 6;

Fig. 7 is a bottom view of the spinner disc shown in Fig. 5;

Fig. 8 is a longitudinal sectional view of a spinner disc portion of a pitch fiber centrifugal spinning apparatus in accordance with a third embodiment of the invention;

Fig. 9 is a cross sectional view of the spinner disc shown in Fig. 8;

Figs. l0 and ll are cross-sectional views similar to Fig. 9 but showing modifications of the spinner disc in the centrifugal spinning in accordance with the third embodiment of the invention;

Fig. l2 is a cross-sectional view showing a spinning condition upon the formation of a shot material in the centrifugal spinning apparatus having a spinner disc provided with no circumferential wall in the side wall thereof according to one of the embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described by way of example with reference to the accompanying drawings.

In Fig. l, there is shown a centrifugal spinning apparatus for pitch fibers, generally designated by reference numeral 2, in accordance with a first embodiment of the invention. The apparatus 2 is provided with a spinner disc 6 including a top wall 6a having a central opening 4, a bottom wall 6b and a side wall 6c connecting the top wall 6a and the bottom wall 6b to each other. A plurality of spinning nozzles 8 are formed in the side wall 6c of the spinner disc 6. The apparatus 2 is provided with a hollow rotary drive shaft (hereinafter referred to as a hollow rotary shaft) mounted on a central portion of the bottom wall 6b of the spinner disc 6 by fastening means such as bolts. The top wall 6a, the bottom wall 6b and the side wall 6c are made of, for example, brass.

Planar heating members l2a and l2b made of electrically heating material such as a Ni-Cr alloy are fixed in contact with outer surfaces of the top wall 6a and the bottom wall 6b of the spinner disc 6 as heating sources for directly heating the walls. In the embodiment shown, the fixing of the planar heating members l2a and l2b is carried out by covering the planar heating members l2a and l2b with cover plates l4a and l4b made of stainless steel and fastening a suitable number of bolts l6a and l6b (see Figs. 2 and 3) between the top wall 6a and the cover plate l4a and the bottom wall 6b and the cover plate l4b. The fixing manner of the heating members l2a and l2b is not limited thereto or thereby. An opening l8 having a somewhat larger diameter than that of a central hole l0a of the hollow rotary shaft l0 is formed at a central portion of the lower cover plate l4b.

The hollow rotary shaft l0 is rotatably supported within a hollow fixed shaft 22 through bearings 20a and 20b. A pulley 24 is mounted at an upper end portion of the hollow rotary shaft l0. As shown in Fig. 4, the hollow rotary shaft l0 is drivingly rotated by a motor 26 through a belt 29 entrained between the pulley 24 and an output shaft of the motor 26.

A circumferential flange 22a extending radially outwardly is formed at a lower end portion of the hollow fixed shaft 22. The circumferential flange 22a serves as an upper cover for closing the central opening 4 of the top wall 6a of the spinner disc 6 with a slight gap or clearance between the opening edge of the top wall 6a and the circumferential flange 22a. Also, a supply pipe 30 for molten pitch is mounted on the circumferential flange 22a, its outlet portion being disposed within the spinner disc 6.

A pair of electric current supply terminals 32a and 32b (34a and 34b) are connected to each planar heating element l2a (l2b). A temperature detecting means such as a thermocouple 36 is connected to the spinner disc 6. The electric current supply terminals 32a and 34a are connected to a wire 38a. The current supply terminals 32b and 34b are connected to a wire 38b. The thermocouple 36 is connected to wires 38c and 38d. These wires 38a to 38d are arranged to extend upwardly through the central hole l0a of the hollow rotary shaft l0. On the upper portions of the hollow rotary shaft l0 and the hollow fixed shaft 22, there is mounted a rotary power supply mechanism 40 connected electrically to the wires 38a to 38d so that an electric current or power may be supplied from the outside of the hollow fixed shaft 22 to the wires 38a to 38d arranged within the hollow rotary shaft l0.

In the embodiment shown, the rotary power supply mechanism 40 is provided with a power supply brush mechanism composed of conductor rings 44a, 44b, 44c and 44d mounted on an outer periphery of the hollow rotary shaft l0 and each having conductor portions 42a, 42b, 42c and 42d, and power supply brushes 48a, 48b, 48c and 48d housed in holders 46a, 46b, 46c and 46d each made of insulating material and fixed to the hollow fixed shaft 22. The brushes 48a to 48d are urged radially inwardly by springs so as to come into pressing contact with the conductor portions 42a to 42d of the supply rings 44a to 44d. In the hollow rotary shaft l0 and portions, corresponding to the conductor portions 42a to 42d, of the supply rings 44a to 44d, there are formed transverse or lateral holes 50a, 50b, 50c and 50d which cause the conductor portions 42a to 42d to be exposed to the central hole l0a of the hollow rotary shaft l0. The above-described wires 38a to 38d are connected to the conductor portions 42a to 42d of the supply rings 44a to 44d through the lateral holes 50a to 50d. Wires (not shown) are connected to the power supply brushes 48a to 48d, led outside of the holders 46a to 46d, and connected to associated components, respectively. It is apparent that the rotary power supply mechanism 40 is not limited to the structure shown in the embodiment.

The centrifugal spinning apparatus 2 is to be used in a pitch fiber spinning system as shown in Fig. 4. The spinning system includes a melting section M and a spinning section S. The centrifugal spinning apparatus 2 is arranged in the spinning section S.

The melting section M has a hopper 52 into which isotropic or mesophase solid pitches made from starting materials such as coal or petroleum pitches are fed. In the hopper 52, the entrained or contained air is expelled therefrom after the solid pitches have been fed, and nitrogen gas is injected thereinto, thus exposing the solid pitches to the nitrogen gas.

A screw type heating and melting device 54 incorporating a heating screw 54a is connected to a bottom portion of the hopper 52. The heating screw 54a is drivingly rotated by a motor 54b. The solid pitches fed into the hopper 52 are supplied to an outlet 54c of the screw end at a constant speed while being heated at temperatures of 300 to 350°C by the rotation of the heating screw 54a. A melting tank 56 is connected to the outlet of the screw end. The heated and molten pitches are fed into the melting tank 56 and stored therein to have a constant head. A gear pump 56b to be driven by a motor 56a is provided at a lower portion of the melting tank 56. The molten pitches are fed to the above-described supply pipe 30 by the gear pump 56b. The molten pitches that have reached the supply pipe 30 are fed to spinner disc 6 of the centrifugal spinning apparatus.

The melting of the solid pitches may be directly carried out in the melting tank 56 if the latter is filled with inert gas. This is of the batch type.

It is possible to continuously melt the solid pitches by using the hopper 52 and the screw type heating and melting device 54.

The melting of the solid pitches in the melting section M is carried out at a temperature at which the pitches are not thermally decomposed.

The centrifugal spinning of the molten pitches by using the centrifugal spinning apparatus 2 will be explained. First of all, a nitrogen gas is supplied into the spinner disc 6 from a pipe (not shown) provided near the supply pipe 30 to expel the air contained in the spinner disc 6 to form a nitrogen atmosphere, before the molten pitches are introduced into the spinner disc 6. An electric power or current is supplied from a power source (not shown) through the supply brushes 48a and 48b of the rotary power supply mechanism 40 to the terminals 32a, 34a, 32b and 34b that are connected through the wires 38a and 38b to these brushes. As a result, the planar heating elements l2a and l2b are heated, thereby heating the top wall 6a and the bottom wall 6b of the spinner disc 6 as well as the side wall 6c thereof. The temperature of the spinning portion in the vicinity of the side wall 6c of the spinner disc 6 is detected by the thermocouple 36. Its current is fed from the supply brushes 48c and 48d of the rotary power supply mechanism 40 through the wires 38c and 38d to a controller (not shown), thereby controlling the amount of the electric supply for the terminals 32c and 34d and controlling the temperature of the spinning portion in the vicinity of the side wall 6c of the spinner disc 6 at constant temperatures of, for example, about 300 to 360°C.

Thus, the molten pitches are supplied from the supply pipe 30 to the spinner disc 6, and at the same time, the hollow rotary shaft l0 is rotated by the motor 26 through the pulleys 24 and 28 and the belt 29, so that the spinner disc 6 is rotated at a high speed of about l400 to 2500 rpm. By the rotation, the molten pitches entering into the spinner disc 6 reaches the spinning nozzles 8 of the side wall 6c. Then, the molten pitches are discharged through the nozzles 8 to the outside and are made fibrous by the air friction with the embinent air, to be spun into pitch fibers.

As described above, the spinning portion in the vicinity of the side wall 6c of the spinner disc 6 is controlled to be kept at constant temperatures in the range of about 300 to 360°C. However, since the planar heating members l2a and l2b are fixed in contact with the top wall 6a and the bottom wall 6b of the spinner disc 6, if the temperatures of the top wall 6a, the bottom wall 6b and the side wall 6c tend to be decreased, heat are supplied immediately from the planar heating members l2a and l2b, thereby controlling the temperatures exactly at the constant temperatures of about 300 to 360°C. Therefore, the spinning portion in the vicinity of the side wall 6c is kept out of the influence of the temperature of the molten pitch. Even if the molten pitch that has not reached the spinning nozzles 8 of the side wall 6c is kept at a relatively low temperature, the molten pitch is immediately heated at the constant temperature of about 300 to 360°C, thereby controlling the temperature of the molten pitch that is passing through the spinning nozzles 8, exactly at the desired level. Therefore, quality changes or faults such as foaming and phase separation in the molten pitch within the spinner disc 6 may be prevented. Also, the fiber formation of the pitch fibers produced through the spinning nozzles 8 may be well performed. Moreover, there is no change in quality of the fibrous products. It is also easy to control the carbon fibers so as to have a desired cross-sectional structure. It is possible to enjoy these advantages even in the case where the discharge rate of the molten pitches from the spinning nozzles 8 is varied or increased. In the case where the discharge rate is increased, it is possible to enhance a productivity of the pitch fibers.

Also, in the above-described centrifugal spinning apparatus 2, the planar heating elements l2a and l2b are fixed in contact with the outer periphery of the spinner disc 6 as a heating means. It is therefore unnecessary to provide any heating means independently of the spinner disc 6. As a result, the apparatus as a whole may be made compact in size, and any extra component to be located below the spinner disc may be dispensed with. Thus, the space below the spinner disc may be used as a free space. In other words, any resistance would not be applied to the spun pitch fibers that are falling, and the transfer of the fibers to a subsequent processing station may be smoothly carried out.

Furthermore, in the above-described centrifugal spinning apparatus in accordance with the embodiment, the power supply terminals 32a, 32b, 34a and 34b and the wires 38a to 38d for the power supply terminals 32a, 32b, 34a and 34b and the thermocouple 36 are arranged to pass through the central hole l0a of the hollow rotary shaft l0 and are connected to the rotary power supply mechanism 40 provided on the hollow rotary shaft l0 and the hollow fixed shaft 22 so that the wires are accessible from the outside of the hollow fixed shaft 22. With such an arrangement, the electric power supply system for the planar heating members l2a and l2b is formed in an effective manner without using any complicated electric wiring for feeding an electric power to the rotary components or members.

Also, in the centrifugal spinning apparatus 2 in accordance with the foregoing embodiment, it is possible to introduce an air flow into the central hole l0a of the hollow rotary shaft l0 from above. In this case, the air flow causes the hollow rotary shaft l0 and the wires within the hollow hole thereof to be cooled, so that these components may be protected from thermal attack or damage. Furthermore, the air flow is directed to the outside from the bottom of the spinner disc 6, so that a force causing the pitch fibers to fly radially outwardly is additionally imparted to the pitch fibers, thus making the pitch fibers in a good fibrous condition.

A second embodiment of the present invention will now be described with reference to Figs. 5 to 7. In Fig. 5, there is shown a centrifugal spinning apparatus for pitch fibers, generally designated by reference numeral 60. In the second embodiment, the same or like members or components as those in the first embodiment will be designated by the same reference numerals or characters.

In the same manner as in the first embodiment, the centrifugal spinning apparatus 60 has a top wall 62a having a central opening 4, a bottom wall 62b and a side wall 62c connecting the top wall 62a and the bottom wall 62b. The apparatus 60 is provided with a spinner disc 62 having a plurality of spinning nozzles 8 (see Fig. 6) formed in the side wall 62c. A hollow rotary shaft l0 is coupled to a central portion of the spinner disc 62. Instead of the planar heating members l2a and l2b used in the first embodiment, the spinner disc 62 is provided with a heating means composed of the top wall 62c, the bottom wall 62b and the side wall 62c per se made of conductive heating material such as Ni-Cr alloy.

Connected to the top wall 62a and the bottom wall 62b of the spinner disc 62 are power supply terminals 32a, 32b, 64a and 64b for supplying an electric power or current to the conductive heating materials forming the walls. The terminals 32a and 32b for the top wall 62a are positioned in the same manner as in the first embodiment but the terminals 64a and 64b for the bottom wall 62b are located at positions different from those of the first embodiment, that is, in the vicinity of an outer circumferential edge of the bottom wall 62b. In the case where the spinner disc per se is made of conductive heating material, it is preferable that, in order to heat the spinning portion near the side wall 62c at a desired temperature, the terminals 64a and 64b for the bottom wall 62b are located at the positions near the outer circumferential edge of the bottom wall 62b.

Since the other structure of the second embodiment is substantially the same as that in the first embodiment, explanations therefor will be omitted.

Also, the centrifugal spinning apparatus 60 in accordance with the first embodiment, a necessary heat quantity may be instantaneously supplied to the desired parts in the same manner as in the first embodiment. It is, therefore, possible to exactly control the temperature of the molten pitch that is passing through the spinning nozzles. Also, since it is possible to keep the molten pitch at a relatively low temperature before the molten pitch reaches the spinning nozzles, it is possible to avoid quality changes such as foaming and polmerization. Also, in the centrifugal spinning apparatus 60 in accordance with the second embodiment, the wires 38a to 38d for the power supply terminals 32a, 32b and 64a and 64b and the thermocouple 36 are arranged to pass through the central hole l0a of the hollow rotary shaft l0, and are connected to the rotary power supply mechanism 40 provided on the hollow rotary shaft l0 and the hollow fixed shaft 22, so that the wires are accessible from the outside of the hollow fixed shaft 22. It is possible to arrange well the electric wiring system for the heating members, i.e. walls, without a necessity to use a complicated structure for supplying the electric power to the rotary components or members.

It will be understood that the centrifugal spinning apparatus according to the second embodiment may offer the same or like effects and advantages as in the first embodiment.

Example I

A spinning operation was conducted by using the centrifugal spinning apparatus 2 according to the first embodiment shown in Figs. I to 3. In this case, the top wall 6a, the bottom wall 6b and the side wall 6c of the spinner disc 6 was made of brass, and the planer heating members l2a and l2b are made of Ni-Cr alloy. A mesophase system pitch was used as a material pitch. The spinning portion in the vicinity of the side wall 6c of the spinner disc 6 was controlled to be kept at a temperature of 3l0°C. The spinner disc 6 was rotated at a rotational speed of 2000 rpm. As a result, pitch fibers having a constant quality, that is, a fibrous diameter of l3.7 microns could be obtained.

Example 2

A spinning operation was carried out by using the centrifugal spinning apparatus 60 shown in Figs. 5 to 7 in accordance with the second embodiment. In this case, the top wall 62a, the bottom wall 62b and the side wall 62c of the spinner disc 62 were made of Ni-Cr alloy. A mesophase pitch was used as a material. The spinning portion in the vicinity of the side wall 62c of the spinner disc 62 was kept at a temperature of 360°C. The spinner disc 62 was rotated at a rotational speed of 2500 rpm. As a result, as is the case of Example I, pitch fibers having a uniform quality, that is, a fibrous diameter of l2.3 microns.

Example 3

The centrifugal spinning apparatus 60 was used as in Example 2, but the spinning was conducted by using a mesophase pitch as a material pitch under the condition that the temperature of the spinner disc was maintained at a temperature of 355°C and the rotational speed of the spinner disc was held at 2000 rpm. As a result, pitch fibers were stable in quality to have a fibrous diameter of l3.4 microns.

Example 4

The centrifugal spinning apparatus as in Example 2 was used, but the spinning was conducted by using a mesophase pitch as a material pitch under the condition that the temperature of the spinner disc was maintained at a temperature of 350°C and the rotational speed of the spinner disc was held at l400 rpm. The obtained pitch fibers have a fibrous diameter of l4.8 microns with a uniform quality.

A centrifugal spinning apparatus according to a third embodiment of the present invention will now be described with reference to Figs. 8 to II, in which the same reference numerals are used to indicated like components or members shown in Figs. I to 4.

As shown in Fig. 8, the centrifugal spinning apparatus comprises a spinner disc generally designated by reference numeral l06. The structure according to the third embodiment is the same as that of the first embodiment except for the spinner disc l06, and hence, explanations therefor will be omitted.

As shown in Fig. 9 showing a primary part of the spinner disc l06, the latter comprises a pair of upper and lower heat radiative surfaces l02a and l02b each of the which extends in a circumferential direction of a side wall l06c. The pair of upper and lower heat radiative surfaces l02a and l02b are formed so as to face to each other and to allow the molten pitch P, discharged from spinning nozzles l0 formed in the side wall l06c, to pass therebetween.

In the structure shown in Fig. 9, the heat radiative surfaces l02a and l02b are adapted to define a circumferential groove l02 which is in communication with the spinning nozzles l08 at a bottom l02c thereof in the spinner disc side wall l06c. The heat radiative surfaces l02a and l02b are defined by opposing surfaces of the circumferential groove l02.

Also, the heat radiative surfaces l02a and l02b may be modified as shown in Fig. l0 in which a pair of flanges l02A and l02B made of, for example, brass are fixed to upper and lower portions of an outlet of each spinning nozzle l08 of a side wall l06c of a spinner disc l06A by suitable fastening means such as bolts. The heat radiative surfaces l02a and l02b are defined by opposing surfaces of the pair of flanges l02A and l02B.

Although, in the structures shown in Figs. 9 and l0, the spinning nozzles l08 are arranged in a single row of orifices in the circumferential direction of the spinner disc side wall l06c, the nozzle arrangement may be modified as shown in Fig. ll. In Fig. ll, three circumferential rows of spinning nozzles l08a, l08b and l08c are formed in the side wall l06c of the spinner disc l06B. The heat radiative surfaces l02a and l02b are formed so as to allow molten pitches Pa, Pb and Pc immediately after the spinning to pass therebetween.

In the centrifugal spinning apparatus in accordance with the third embodiment, the heat radiative surfaces l02a and l02b formed in the side wall l06c of the spinner disc l06 are also heated at a temperature of the side wall l06c of the spinner disc l06. Therefore, the molten pitch P (see Fig. 9) discharged just from the spinning nozzles l08 is heated by the upper and lower heat radiations from the heat radiative surfaces l02a and l02b. Thus, the molten pitch P is prevented from being rapidly cooled thereat. Also, in the space between the heat radiative surfaces l02a and l02b, that is, within the circumferential groove l02, the air friction induced by the high speed rotation of the spinner disc l06 is somewhat degraded but there is a remarkable air friction outside of the circumferential groove l02. Accordingly, the discharged molten pitch P is drawn or sucked by the latter air friction. As a result, the just discharged molten pitch P is drawn to be elongated by the ambient air friction while keeping a low viscosity, and then, the molten pitch is allowed to fly in the tangential direction under the sufficiently fibrous condition.

It is apparent that the same effects and advantages may be ensured in the case of the spinner discs l06A and l06B shown in Figs. l0 and ll.

In the following experimental examples, the pitch fibers were spun in the centrifugal spinning apparatus in accordance with the third embodiment of the invention. A comparative experiment was also conducted. In all the experiments, the structure of the centrifugal spinning apparatus except for the spinner disc was that shown in Fig. l. In the respective experiments, (l) the structure shown in Fig. 9, (2) the structure shown in Fig. l0, (3) the structure shown in Fig. ll and (4) the structure shown in Fig. 2 were used as the spinner disc. In the case (4), the centrifugal spinning apparatus had the spinner disc in which the spinning nozzles were formed in the flat outer circumferential wall in accordance with the first embodiment. An isotropic pitch was used as a material.

As was apparent from the following table, the shot rate was drastically decreased from 30% to 3-5% in accordance with the third embodiment of the invention. Also, the fibrous diameter deviation was in the range of 2.4-3.0 microns according to the third embodiment. The uniformity of the fibrous diameter according to the third embodiment was considerably superior to that according to the first embodiment.

	Fig. 9	Fig. 10	Fig. 11	Fig. 2
Nozzle Diameter	0.4 mm	0.4 mm	0.4 mm	0.4 mm
Nozzle Number	360	360	1080	1080
Heat Radiative Surfaces	provided (groove)	provided (flange)	provided (gloove)	not provided
Heat Radiative Surface Distance	3.0 mm	3.0 mm	10.0 mm	-
Width of Heat Radiative Surfaces	8.0 mm	8.0 mm	7.0 mm	-
Spinner Disc Diameter	300 mm	300 mm	300 mm	300 mm
Average Fibrous Diameter	15.8 µ	15.2 µ	17.0 µ	17.3 µ
Deviation of Fibrous Diameter	2.5 µ	2.4 µ	3.0 µ	5.5 µ
Shot Rate	3%	3%	5%	30%
RPM	1400 rpm	1400 rpm	1400 rpm	1400 rpm
Spinner Temp.	310°C	310°C	310°C	310°C
Supply Pitch Temp.	330°C	330°C	330°C	330°C

As is apparent from the foregoing description, in the centrifugal spinning apparatus for pitch fibers in accordance with the present invention, planar heat radiative members made of conductive heating material are fixed in contact with outer surfaces of at least the top wall and the bottom wall of the spinner disc, or otherwise the top wall, the bottom wall and the side wall per se are formed of conductive heating material, thereby directly heating the spinner disc. Therefore, it is possible to replenish a heat quantity rapidly and to exactly control a temperature of a molten pitch passing through the spinning nozzles. Thus, it is possible to produce a high quality carbon fibers and at the same time to make the apparatus as a whole compact without enlarging a total dimension caused by a heating means. Accordingly, it is unnecessary to provide a wide equipment space for the apparatus. Furthermore, since there is no component or member below the spinner disc, this space may be used freely. There is no hindrance against the downward fall of spun pitch fibers. Therefore, it is possible to smoothly move the fibers to a subsequent processing station.

Also, in the case where the wires connected to the heating means for electric power supply are arranged to pass through the hollow rotary shaft rotating the spinner disc at a high speed and to be connected to the rotary power supply mechanism provided on the hollow rotary shaft and the hollow fixed shaft rotatably supporting the hollow rotary shaft, the apparatus as a whole may be made compact.

Also, in the case where the heat radiative surfaces are formed so as to face each other and to allow the molten pitch, discharged from the spinning nozzles, to pass therebetween, the molten pitch immediately after the outlets of the nozzles is heated by the upper and lower heat radiations from the heat radiative surfaces, to thereby prevent it from being rapidly cooled. The molten pitch is elongated under the condition of low viscosity by the air friction induced by the high speed rotation of the spinner disc, and is made fibrous. Therefore, it is possible to reduce the shot rate considerably and to make uniform the fibrous diameter. The high quality pitch fibers may be produced.

Claims

I. In a centrifugal spinning apparatus including a spinner disc (6; 62; 106) having a top wall (6a; 62a; I06a), a bottom wall (6b; 62b; 106b) and a side wall (6c; 62c; 106c) connecting said top wall and said bottom wall to each other, a plurality of spinning nozzles (8; 108; I08a, I08b, I08c) being formed in said side wall, said spinner disc being rotated at a high speed to thereby spin a molten pitch, fed into said spinner disc, into pitch fibers through said spinning nozzles, said centrifugal spinning apparatus comprising an improvement in which a heating means (I2a, I2b; 62a, 62b, 62c) is provided to said spinner disc (6; 62; 106), said heating means being made of electrically conductive heating material.

2. A centrifugal spinning apparatus as recited in claim I, wherein said heating means comprises planar heating members (I2a, I2b) each fixed in contact with outer surfaces of at least said top wall (6a; 106a) and bottom wall (6b; 106b) of said spinner disc (6; 106), each of said planar heating members being made of said electrically conductive heating material.

3. A centrifugal spinning apparatus as recited in claim I, wherein said top wall (62a), said bottom wall - (62b) and said side wall (62c) of said spinner disc (62) is made of said electrically conductive material.

4. A centrifugal spinning apparatus as recited in claim I, further comprising a hollow fixed shaft (22) coaxially disposed above said spinner disc (6; 62; 106); a hollow rotary shaft (I0) coaxially disposed at a central portion of said spinner disc and rotatably supported to said hollow fixed shaft for rotating said spinner disc at the high speed; and electric power supply means (32a, 32b, 34a, 34b, 38a, 38b, 40) electrically connected to said heating means, for supplying an electric power to said heating means to heat said heating means, wherein said electric power supply means comprises electric wiring means (38a, 38b) electrically connected to said heating means and extending upwardly through a central hole (I0a) of said hollow rotary shaft, and a rotary power supply mechanism (40) electrically connected to said electric wiring means and enabling to supply the electric power to said electric wiring means from the outside while rotating said electric wiring means together with said spinner disc and said hollow rotary shaft.

5. A centrifugal spinning apparatus as recited in claim 4, wherein said rotary power supply mechanism - (40) comprises an electrically conductive brush mechanism provided with conductive rings (44a to 44d) having conductor portions (42a to 42d) formed around an outer circumferential wall of said hollow rotary shaft (I0), and electrically conductive brushes (48a to 48d) pressed against to said conductor portions of said conductive rings, said brushes being received in holders (46a to 46d) mounted on said hollow fixed shaft (22), said electric wiring means (38, 38b) being connected to said conductive rings.

6. A centrifugal spinning apparatus as recited in claim I, wherein heat radiative surfaces (I02a, I02b) are provided on the side wall (I06c) of said spinner disc (I06), said heat radiative surfaces extending in a circumferential direction of said side wall and being positioned to face to each other to allow the molten pitch (P; Pa, Pb, Pc), discharged through said spinning nozzles (I08; 108a, I08b, I08c), to pass between said heat radiative surfaces.

7. A centrifugal spinning apparatus as recited in claim 6, wherein a circumferential groove (I02) having a bottom to which said spinning nozzles (I08; 108a, I08b, I08c) are open is formed in said side wall (I06c) of said spinner disc (I06).

8. A centrifugal spinning apparatus as recited in claim 6, wherein a pair of flanges (I02A, I02B) located above and blow an outlet of each of said spinning nozzles (I08) are fixedly secured to said side wall (I06c) of said spinner disc (I06), said heat radiative surfaces being defined by opposing surfaces (I02a, I02b) of said pair of flanges.

FIG. 1

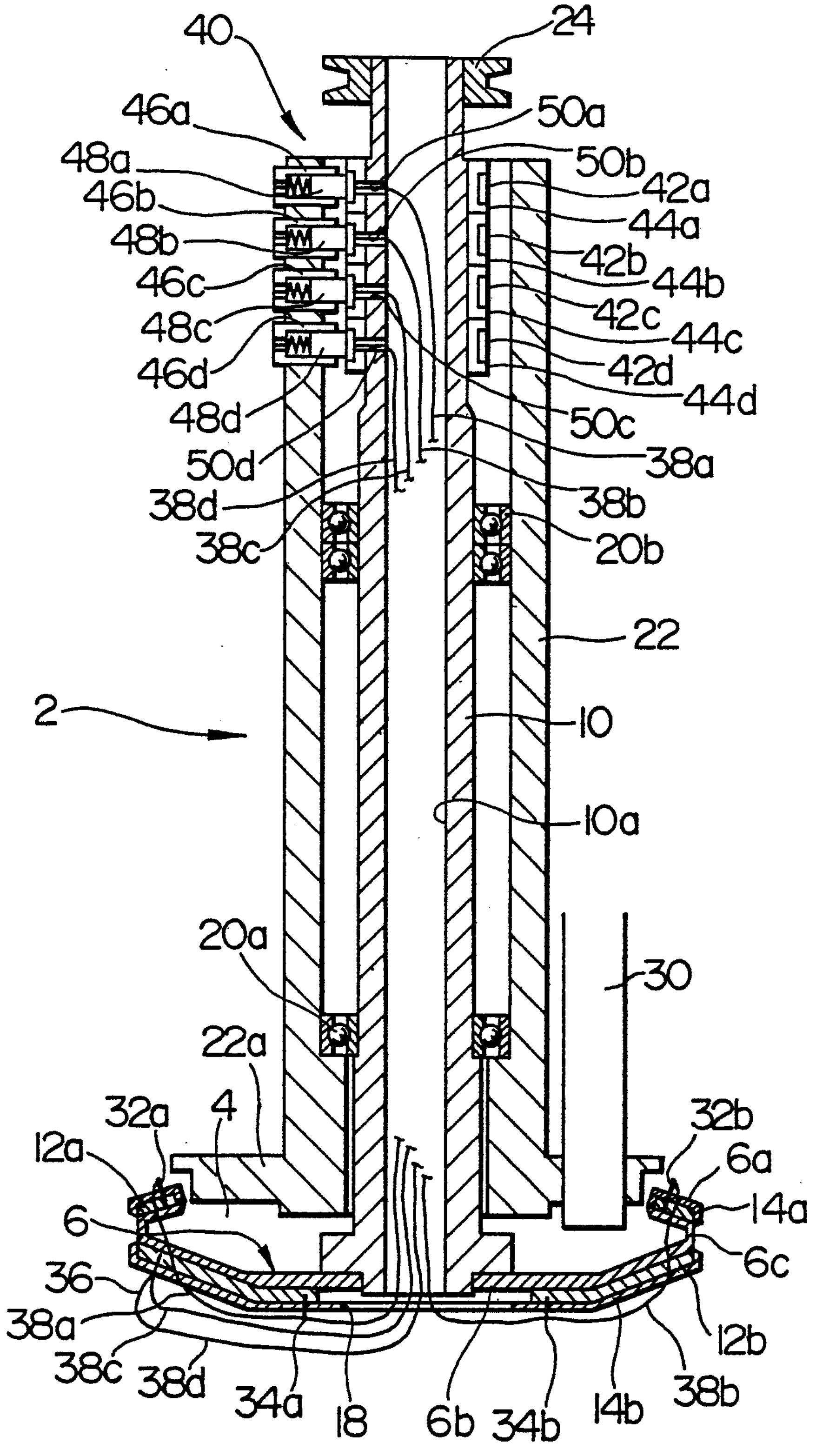
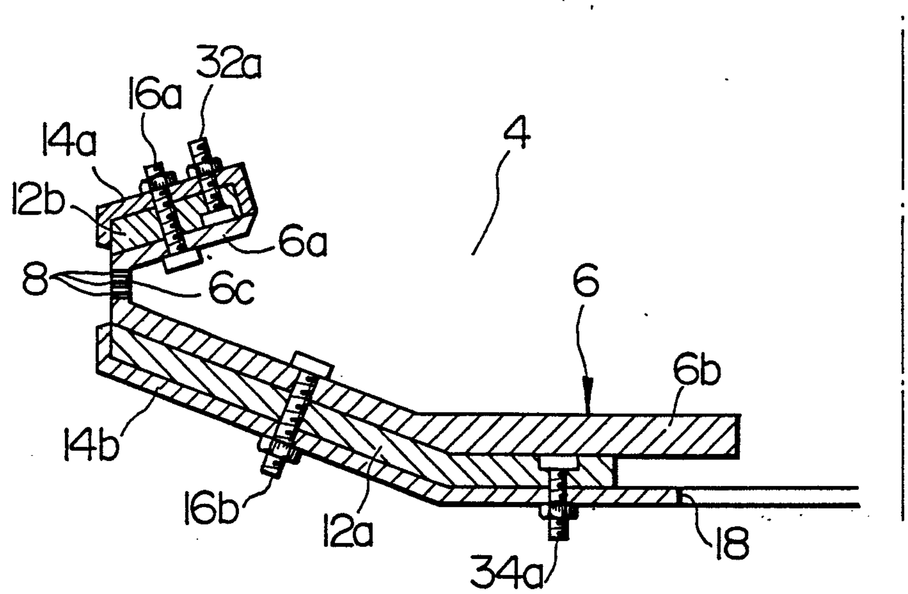

40
24
46a
50a
48a
50b
46b
42a
44a
48b
42b
46c
44b
48c
42c
44c
46d
42d
48d
44d
50c
50d
38a
38d
38b
38c
20b
22
2
10
10a
20a
30
22a
32a
4
32b
12a
6a
14a
6
6c
36
38a
12b
38c
38d
34a
18
6b
34b
14b
38b

FIG. 2


32a
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14a
12b
4
6a
8
6c
6
6b
14b
16b
12a
34a
18

FIG. 3

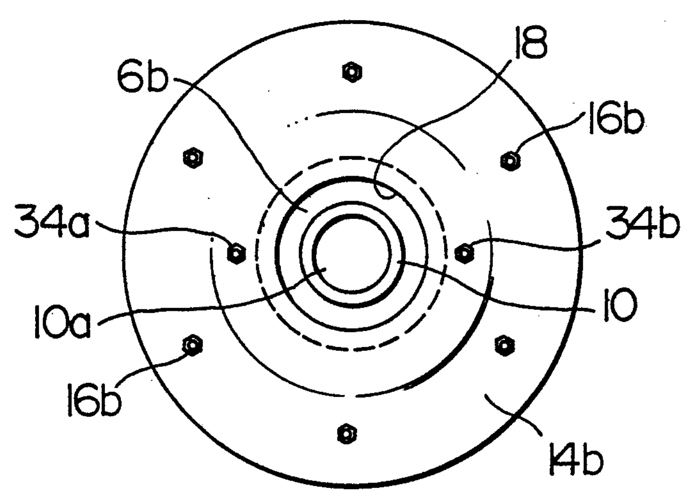
18
6b
16b
34a
34b
10a
10
16b
14b

FIG. 4

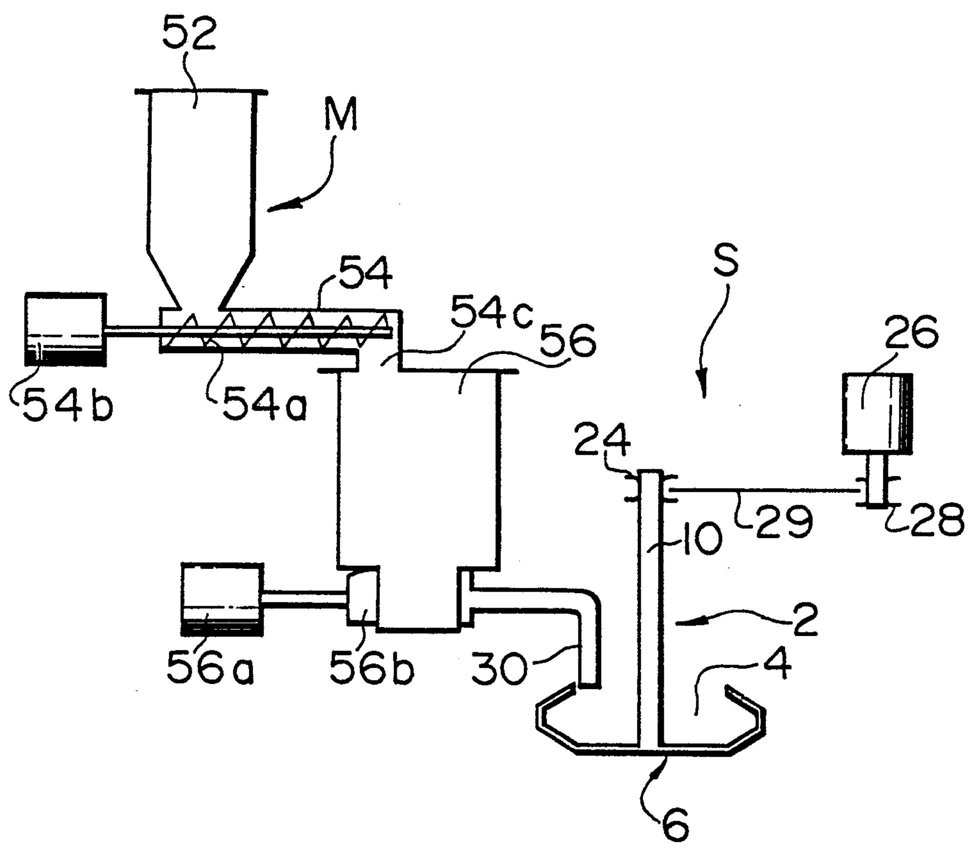

FIG.5

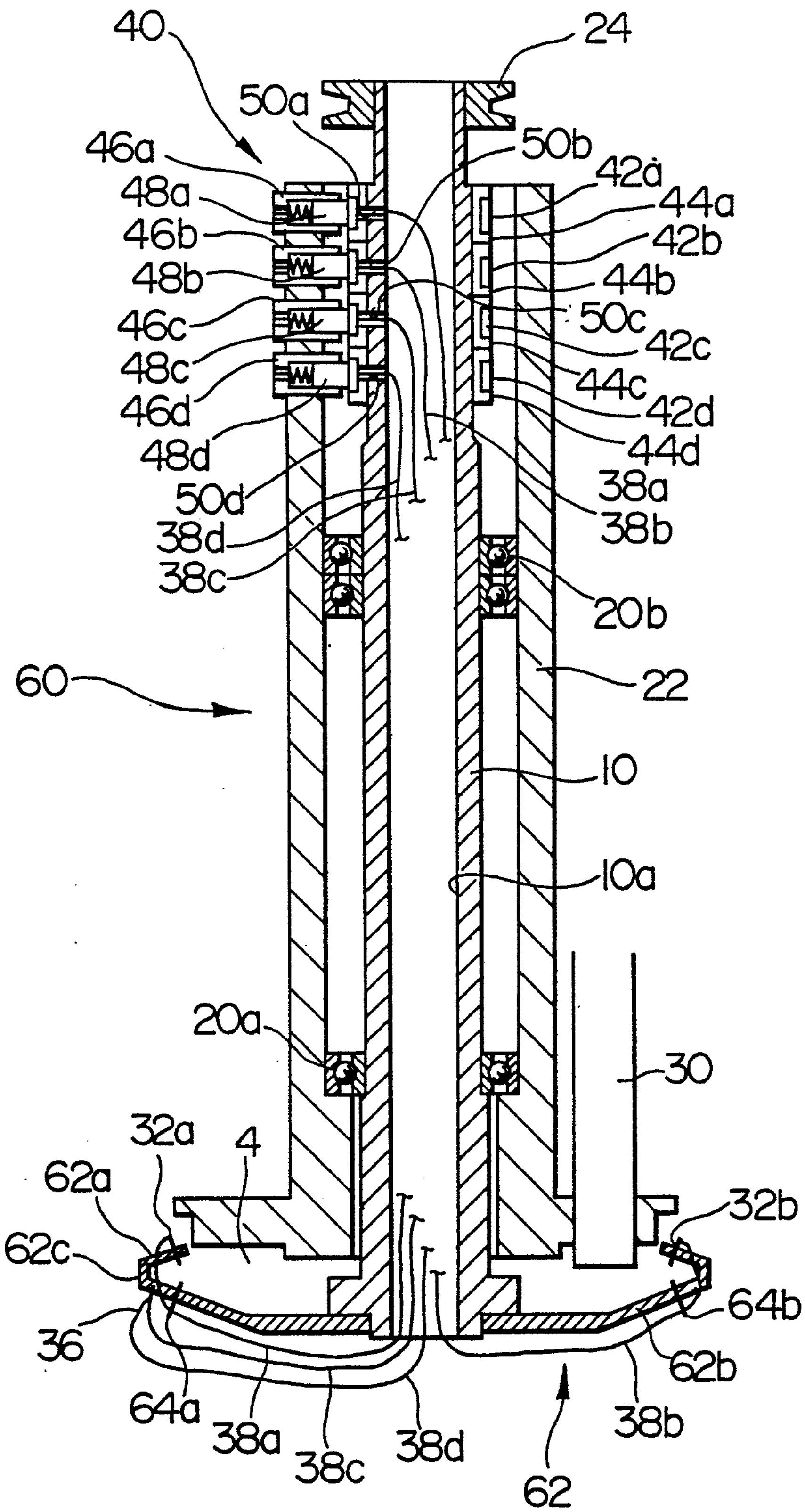
40
24
50a
50b
46a
42a
48a
44a
46b
42b
48b
44b
50c
46c
42c
48c
44c
46d
42d
48d
44d
50d
38a
38d
38b
38c
20b
60
22
10
10a
30
20a
32a
4
62a
32b
62c
64b
36
62b
64a
38a
38c
38d
38b
62

FIG. 6

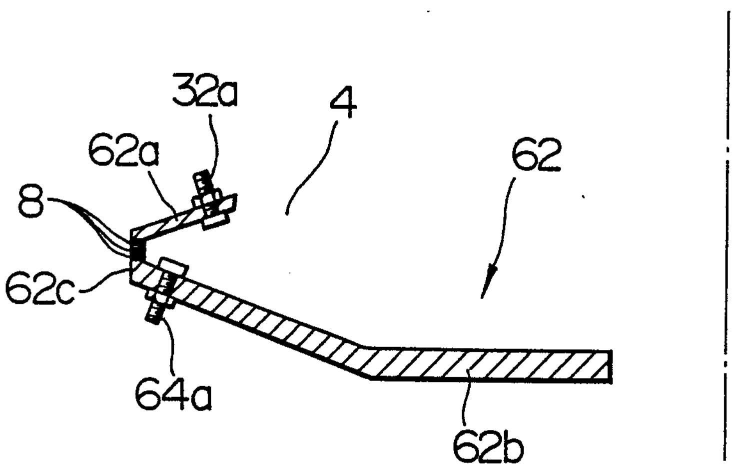

FIG. 7

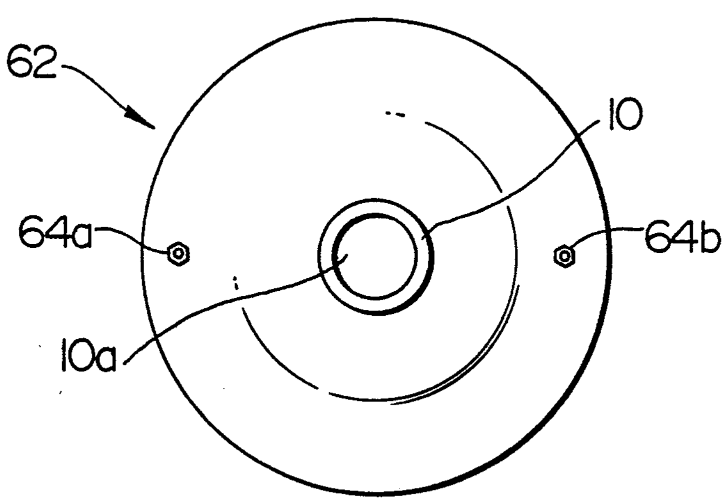

FIG. 8

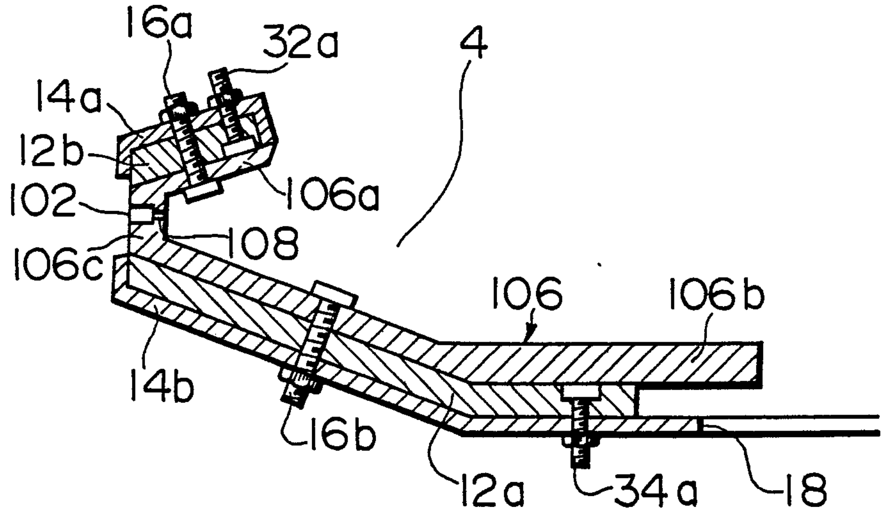
16a
32a
4
14a
12b
106a
102
108
106c
106
106b
14b
16b
12a
34a
18

FIG. 9

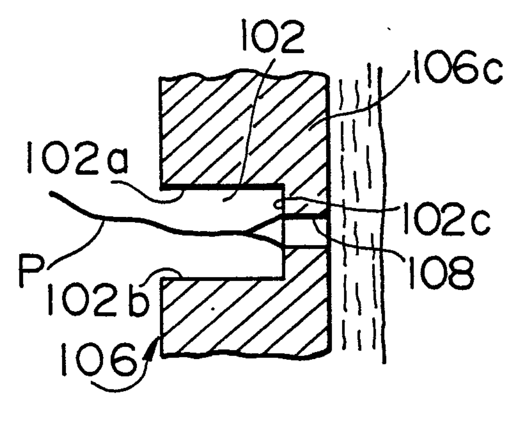
102
106c
102a
102c
P
108
102b
106

FIG. 10

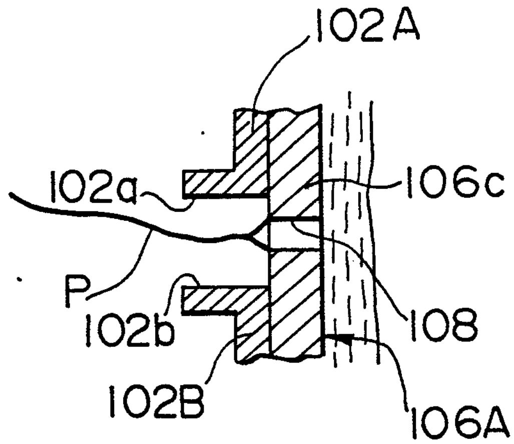

FIG. 11

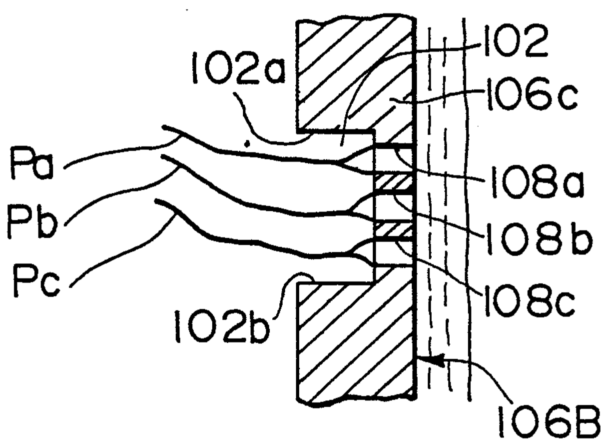

FIG. 12