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(54) A HYDROMATIC BRAKING DEVICE FOR A VERTICAL ROTOR SHAFT

(71) I, PER OVE CHRISTENSEN, a citizen of Denmark, of No. 46 Sønderdalen, 2860 Søborg, Denmark, do hereby declare the invention, for which I pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present inventon relates to a hydrodynamic braking device for a vertical rotor shaft, particularly for a wind- or water-powered rotor.

With the increasing interest for the utilization of natural energy sources such as wind and water power, a growing demand has arisen for methods and installations which may lead to a more optimal and economic operation with high efficiency for rotor systems to be used in wind or water power plants.

The working conditions of rotor systems in wind power plants are usually characterized by the so-called power ratio indicating the ratio $R_{\omega v}$: of the circumferential speed of the rotor to the flow velocity of the medium, in this case air, acting on the rotor. In the case of wind power rotors, an economic optimal conversion of energy can normally only be obtained within a relatively narrow range of power ratio values and at moderate flow velocities, in which the rotor torque increases by the second power of the flow velocity.

At very high flow velocities where a considerable increase in the energy conversion occurs this quantity increases by the third power of the flow velocity, it will normally be unreasonably expensive to proportion the machine parts of the rotor system to be able to resist the stresses which will occur in operation at higher power ratios.

Therefore, at such high and relatively rarely occurring flow velocities, a suitable reduction of the power ratio is usually aimed at in order to avoid overloading. In rotor systems rotating about a horizontal axis, this will not present great difficulties, since rotors of this kind are usually constructed so that the rotary plane may be turned around a vertical axis out of the wind direction, whereby the power ratio is reduced.

The present invention is particularly related to rotor systems having a vertical rotor shaft, such as wind-powered rotors of the Darrieus type. In the rest condition, rotors of this kind will usually be statically balanced, so that a separate accessory motor such as an electric motor is required to put the rotor into operation. However, the use of rotor systems of this kind has hitherto presented serious difficulties due to the problems of controlling the energy development which increases by the third power of the wind velocity.

According to the invention, a hydrodynamic braking device for a vertical rotor shaft is provided, which comprises a brake container with bearings for said rotor shaft for positioning a part thereof in said container, a tank for containing a supply of brake fluid, a pump conduit for connecting said tank with the lower part of said brake container, a pumping device associated with said pump conduit and arranged on said rotor shaft in said lower part of the brake container for pumping brake fluid from said tank into said container at a pumping rate dependent on the rotational speed of said rotor shaft, return means for returning brake fluid from said brake container into said tank at a flow rate dependent on the brake fluid level in said brake container, and at least one hydro-dynamic brake member mounted on said rotor shaft within said brake container at a position higher than said pumping device, said pump conduit and said return means being connected with said brake container in such a way as to permit the brake fluid level in said container to be between said pumping device and said brake member in the rest condition of said rotor shaft.

As soon as the rotor shaft has been put into operation, the pump will start to supply brake fluid to the brake container, and when the fluid level rises above the brake member mounted on the rotor shaft, the braking action will begin. The braking device functions so that at a given rotational speed of the rotor shaft, the fluid quantity supplied into the brake container by means of the pump will at rotational speeds in a certain rotating range equal the fluid quantity returned into the tank by the return means. At increasing rotational speeds of the rotor shaft, the fluid level in the brake container will rise, and the braking action will be strengthened, and simultaneously a greater quantity of brake fluid will be returned into the supply in the tank. Thus, the braking action is associated directly with the rotor shaft speed.

In a preferred embodiment of the braking device, the pump comprises by a pump impeller mounted on said rotor shaft in the lower part of said brake container below said brake member, and said pump conduit comprises a suction pipe connected to the bottom of said container, said brake fluid supply being of such a magnitude that said impeller is submerged in the brake fluid level in said container in the rest condition of said rotor shaft.

A further increased security at high flow velocities and high rotational speeds of the rotor shaft may be obtained, if the braking device comprises at least two hydro-dynamic brake members, one of which is mounted on said rotor shaft at a relatively short distance above said pump impeller and is of such a construction that when being submerged by brake fluid, it will exert a braking action on said rotor shaft to cause the same to operate in a prescribed power ratio range, in which the quantity of brake fluid drawn into said brake container substantially equals the quantity of brake fluid returned into said tank by said return means, whereas each further brake member is arranged at such a further distance above said one brake member and is of such a construction that it will be submerged in said brake fluid at a brake fluid level in said container corresponding to a predetermined high value of the rotational speed of said rotor shaft and thereby exert an additional braking action on said rotor shaft tending to lower its rotational speed towards decreasing power ratio values.

The or each said further brake member may, in particular, be constructed to brake said rotor shaft until its slows to standstill. Thereby, the rotor system will be brought into statical- balance and may only be started again by means of the separate accessory motor.

In the following the invention will be explained in further detail with reference to the accompanying schematic drawings, in which

Fig. 1 shows a simple embodiment of a braking device according to the invention, and

Fig. 2 shows the operational characteristic of this braking device.

A vertical rotor shaft 1 which may belong, for example, to a wind-powered rotor of the Darrieus type is journalled by means of bearings 2 and 3 in an upstanding brake container 4, in the lower part of which a pump impeller 5 is mounted on the rotor shaft 1.

In the embodiment shown, the brake container 4 is completely surrounded by a tank 6 containing a supply of brake fluid, which may be water. A suction conduit 7, which in this case may be a rigid tube, extends downwards from the pump impeller 5 to have its other end located near the bottom of the tank 6.

In the brake container 4, two hydrodynamic brake members are mounted on the shaft 1 in addition to the pump impeller, one of which brake members has the form of a brake wheel 8 arranged at a short distance above the pump impeller 5, both the pump impeller and said brake wheel being, for example, of the centrifugal impeller type, whereas the other brake member in the embodiment shown is illustrated as a kind of propeller wheel 9 having relatively large blades and being positioned in the upper part of brake container 4.

To return brake fluid from the brake container 4 into the tank 6, a number of return holes 10 are formed at different heights in the vertical side walls of the container. The size and number of these holes will have to be selected in accordance with the braking action and pump capacity desired in the actual application and will to a major extent have to be determined by practical experiments.

In the simple embodiment shown, a row of return holes 10 are situated in the lower part of the container 4 at a height immediately above the pump impeller 5 to secure that in the rest condition of the rotor shaft the brake fluid level in container 4 will just cover the pump impeller 5 but not the brake member and, thereby, result in a minimum load when putting the rotor shaft 1 into operation.

At higher levels in the container 4, two further rows of return holes are situated at a relatively short distance above the brake wheel 8 and opposite the brake member 9, respectively.

In connection with this arrangement of return holes, the brake fluid supply in the tank 6 in the present embodiment is of such a magnitude that in the rest condition the fluid levels in the tank 6 and the container 4 are the same, such as indicated by a dashed line 11.

In the operational characteristic shown in Fig. 2, the dashed curves *a*, *b* and *c* show the braking power *p* exerted by the pump impeller 5, the brake wheel 8 and the upper brake member 9, respectively, as functions of the rotational rate *n* of the rotor shaft 1, whereas the solid curve indicates the total operational characteristic of the braking device.

When the rotor shaft 1 has been put into operation, brake fluid will be drawn up into the brake container 4 through the suction pipe 7 by means of the pump impeller 5. With increasing speed of rotation, the fluid will rapidly overflow the lowermost row of return holes 10 and the brake wheel 8, whereby a suddenly increased braking action will be exerted on the rotor shaft 1 in addition to the braking action coming from the pump impeller 5 itself. In the normal working range at moderate flow velocities, the fluid level will typically vary around the dot-and-dash line 12 to give a braking power within the region of the solid line operational characteristic in Fig. 2 extending between the two abrupt jumps in the braking power, since at a given number of revolutions the fluid quantity drawn into the brake container 4 from the tank 6 by means of the pump impeller 5 will equal the fluid quantity returned from the brake container 4 to the tank 6 through the two lower rows of return holes 10.

When the rotational speed increases, the fluid level as well as the braking power will also increase, and if the rotational speed decreases, the fluid level as well as the braking power will also decrease.

In case of a very high rotational speed, the fluid level in the container 4 may rise over the upper brake member 9, whereby a further very strong braking action leading to a rapid retardation and reduction of the rotational speed will be obtained, as shown in Fig. 2. The brake member 9 may advantageously be constructed to effect braking of the rotor shaft until standstill at a fluid level corresponding to a predetermined upper limit of the rotational speed.

Since as a result of the function of the braking device, the brake fluid, such as water which is circulated between the brake container 4 and the tank 6 will be subject to considerable heating, measures may be taken to utilize the heat thus developed. For this purpose, a heat exchanger 13 of suitable configuration may be arranged in the tank 6 as schematically indicated in Fig. 1.

The invention is not in any way limited to the simple embodiment described and shown. Thus, the brake container 4 need not be combined with the tank 6 but may be connected to a separate tank through individual pump and return conduits, the return conduits only having to be constructed and connected to the brake container so that the fluid quantity returned to the tank depends on the fluid level in the brake container.

Furthermore, more than one brake wheel may be arranged in the brake container, if necessary, and the pump impeller 5, the brake wheel 8 and the upper brake member 9 may have another construction than that described in the foregoing.

WHAT I CLAIM IS:—

1. A hydro-dynamic braking device for a vertical rotor shaft, comprising a brake container with bearings for said rotor shaft for positioning a part thereof in said container, a tank for containing a supply of brake fluid, a pump conduit for connecting said tank with the lower part of said brake container, a pumping device associated with said pump conduit and arranged on said rotor shaft in said lower part of the brake container for pumping brake fluid from said tank into said container at a pumping rate dependent on the rotational speed of said rotor shaft, return means for returning brake fluid from said brake container into said tank at a flow rate dependent on the brake fluid level in said brake container, and at least one hydro-dynamic brake member mounted on said rotor shaft within said brake container at a position higher than said pumping device, said pump conduit and said return means being connected with said brake container in such a way as to permit the brake fluid level in said container to be between said pumping device and said brake member in the rest condition of said rotor shaft.

2. A hydro-dynamic braking device as claimed in claim 1, wherein said pump conduit comprises a suction pipe connected to the bottom of said container and said pumping device comprises a pump impeller communicating with said suction pipe.

3. A hydro-dynamic braking device as claimed in claim 1 or claim 2, comprising at least two hydro-dynamic brake members, one of which is mounted on said rotor shaft at a relatively short distance above said pumping device and is of such a construction that when submerged in the brake fluid, it will exert a braking action on said rotor shaft to cause the shaft to operate in a prescribed speed range, in which the

quantity of brake fluid drawn into said brake container substantially equals the quantity of brake fluid returned into said tank by said return means, whereas the or each further brake member is arranged at such a further distance above said one brake member and is of such a construction that it will be submerged in said brake fluid at a brake fluid level in said container corresponding to a predetermined higher value of the rotational speed of said rotor shaft and thereby exert an additional braking action on said rotor shaft tending to reduce its rotational speed.

4. A hydro-dynamic braking device as claimed in claim 3, wherein the or at least one of said further brake members is arranged to brake said rotor shaft until it slows to standstill.

5. A hydro-dynamic braking device as claimed in any one of the preceding claims wherein said brake container is surrounded by said tank, and said return means are constituted by a number of return holes formed at different heights in upstanding side walls of said brake container.

6. A hydro-dynamic braking device as claimed in claim 5, wherein the lowermost return holes are situated at a height immediately above said pumping device, and said brake fluid supply is of such a magnitude that the brake fluid levels in said tank and said brake container are the same in the rest condition of said rotor shaft.

7. A hydro-dynamic braking device for a vertical rotor shaft, substantially as described hereinbefore with reference to the accompanying drawings.

8. A wind- or water-powered rotor comprising a hydro-dynamic braking device according to any one of the preceding claims.

MEWBURN ELLIS & CO.,
Chartered Patent Agents,
70-72 Chancery Lane,
London WC2A 1AD.
Agents for the Applicant.

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1559089 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1

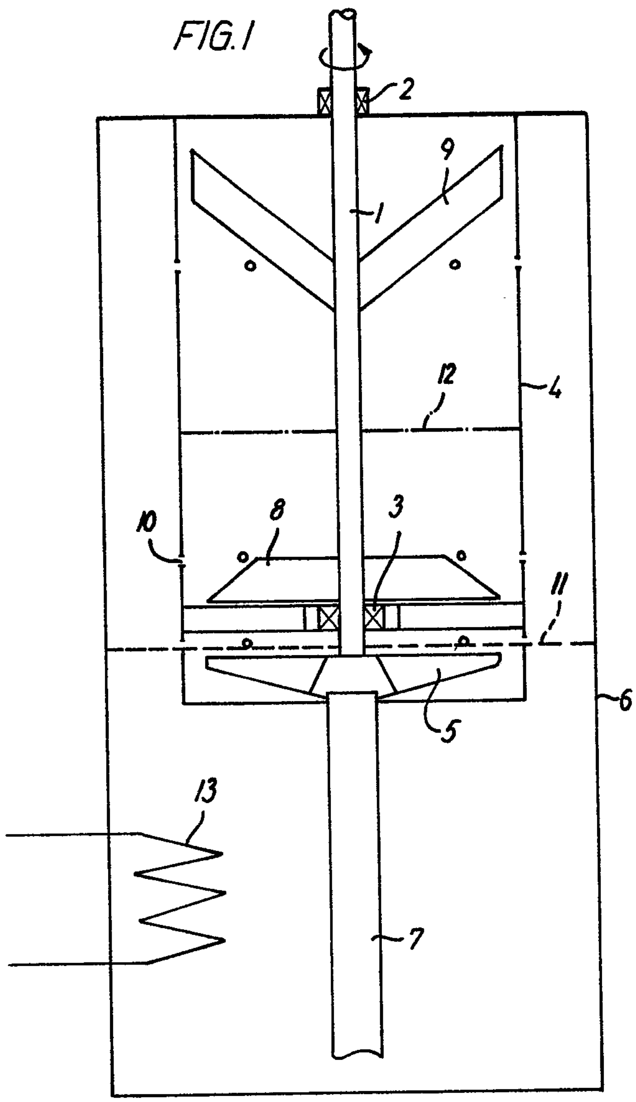

FIG.2