United States Patent

Laing

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[54] CENTRIFUGAL PUMP WITH MAGNETIC COUPLING

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[51] **Int. Cl.** **F04b 17/00,** F04b 35/04, H02k 5/10, H02k 49/00, H02p 15/00

[58] **Field of Search** 417/420, 353; 310/103, 104, 310/105

[56] **References Cited**

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Primary Examiner—Robert M. Walker

[57] **ABSTRACT**

A motor driven centrifugal pump with magnetic transmission comprising a permanent magnetic pole ring and a soft iron magnetic pole ring whereby means are provided for reducing the magnetic flux which determines the torque and which flows through the two pole rings.

28 Claims, 10 Drawing Figures

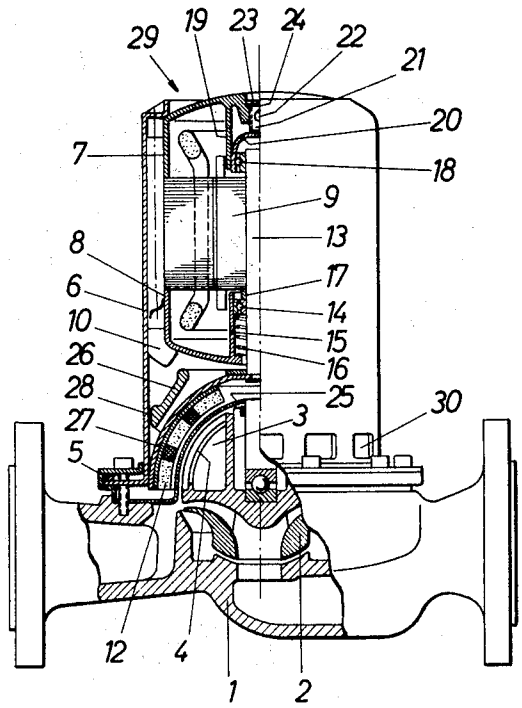


FIG. 1

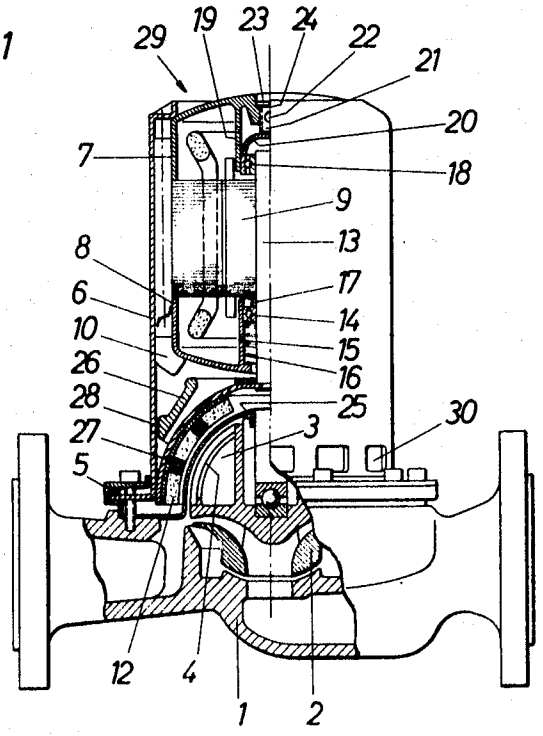
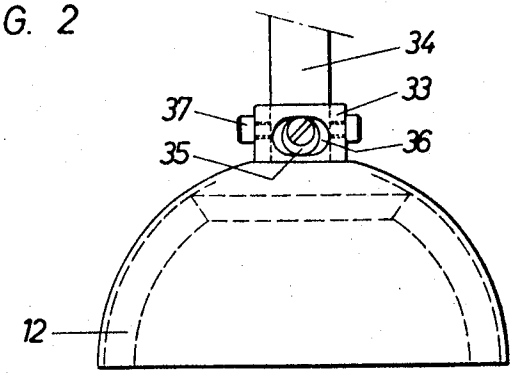


FIG. 2



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FIG. 4

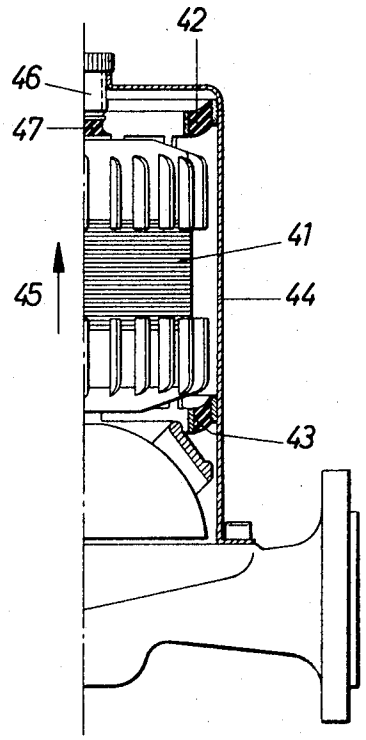
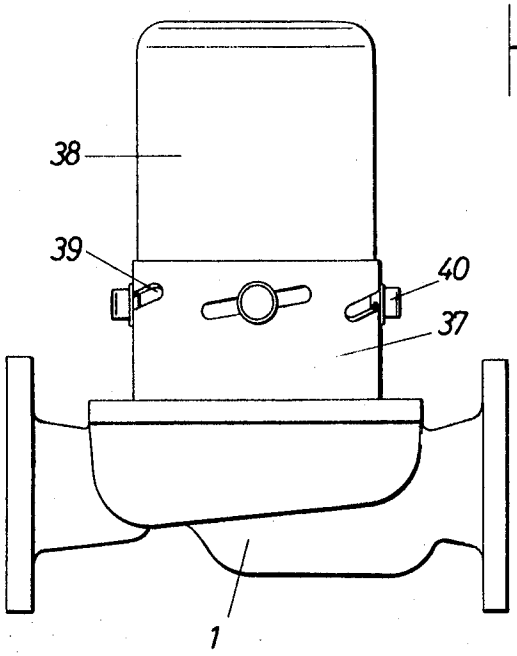


FIG. 3



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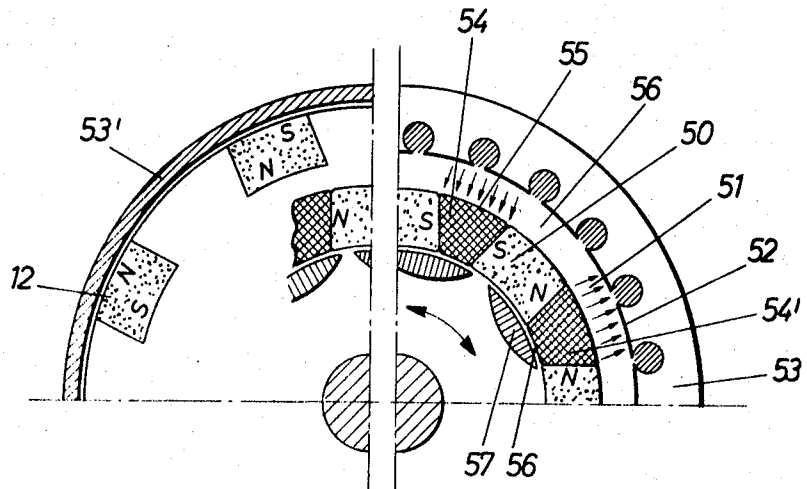


FIG. 5b FIG. 5a

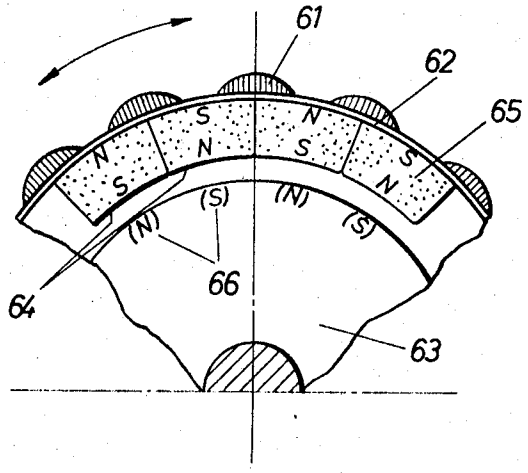
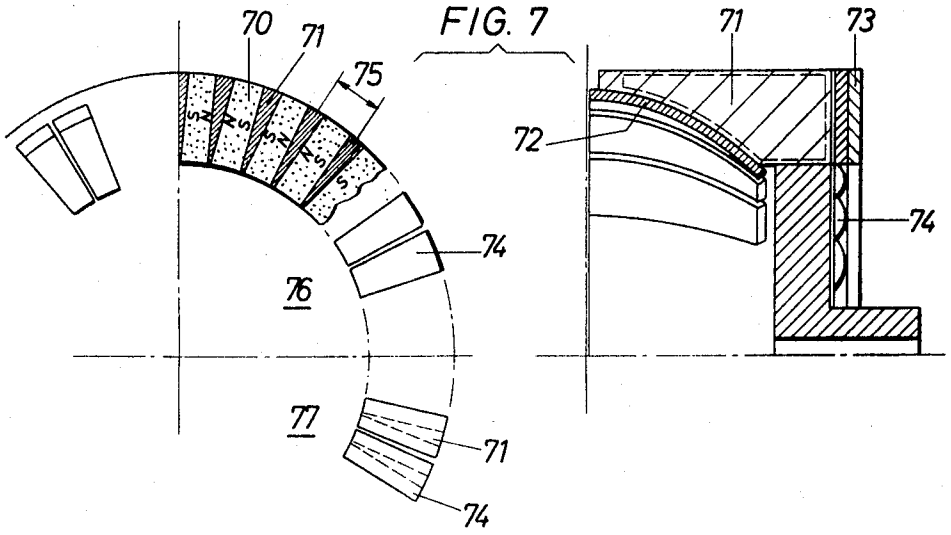


FIG. 6

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FIG. 7



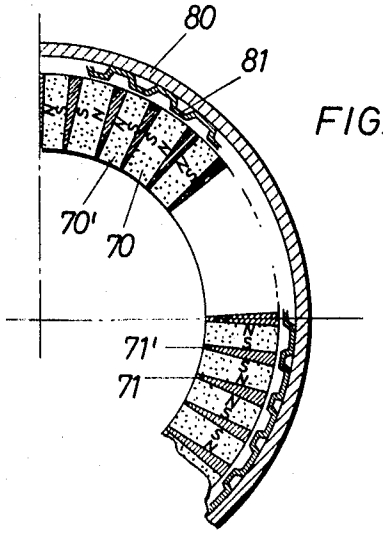


FIG. 8

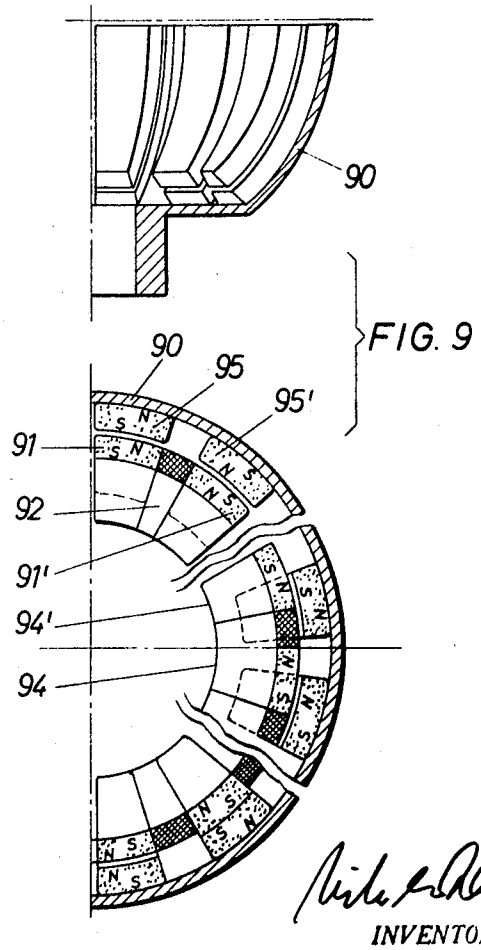


FIG. 9

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CENTRIFUGAL PUMP WITH MAGNETIC COUPLING

THE PRIOR ART

Pumps with a magnetic transmission coupling have the advantage that the pump housings are hermetically sealed by means of a magnetically permeable separating wall. They have the further advantage that they prevent a predetermined torque being exceeded, e.g., when conveying liquids of excessive viscosity or in the case of ingress of clogging solid bodies, by the use of permanent or hysteresis magnets for one of the pole rings of the coupling and a permanent magnet for the other pole ring of the coupling, in that the coupling drops out of synchronism and thereafter no longer transmits any torque. With a view to adapting the conveyance characteristics to the resistance characteristics, the diameter of the runner is, in the case of all larger pumps, reduced by turning on a lathe until the throttle characteristics which is a function of the runner diameter cuts the resistance characteristic of the power system at the desired operating point. This method of adaptation is irreversible, and if the resistance in the power system is subsequently increased, a new pump runner has to be installed.

With a view to avoiding this disadvantage, many pumps are provided with a controllable bypass. The lower the desired operating pressure, the greater is the proportion of the throughput which is returned from the pressure side to the suction side through the bypass. Against this advantage of adjustability there is the disadvantage of low hydraulic efficiency. The smaller the product the pressure × quantity conveyed by the pump, i.e., the lower the hydraulic power provided, the greater is the total power demand and thus, for example, the electric power consumption of the driving motor. Particularly in the case of pumps which are operated contunuously and over long periods, this adjustable control results in a considerable increase in energy consumption as compared with the conventional method first described.

DESCRIPTION OF THE INVENTION

The invention avoids these disadvantages. The runners of the pumps in accordance with the invention are driven through a magnetic coupling which consists only of a permanent magnet pole ring and a soft magnetic pole ring which preferably has a squirrel cage winding or a layer of material of high electric conductivity. Furthermore the invention uses means whereby the magnetic flux which determines the torque and which flows through the two pole rings can be reduced. This can be done in the following manner:

a. by increasing the air gap between the pole rings
b. by producing or increasing an eddy current in the separating wall
c. by partially short-circuiting adjacent poles by means of soft iron or permanent magnets
d. by increasing the magnetic reluctance in the return path region between adjacent poles.

The like permanent magnet pole rings of a magnetic coupling in combination with a second permanent magnet pole ring driving the runner or also a soft magnetic pole ring with salient geometric poles or also a pole ring made of hysteresis material enable the stalling torque to be adjusted, so that one and the same coupling may be used for motors of different maximum torques.

Alternative embodiments provide adjustability during operation and during stadstill of the pump respectively. Adjustability of the slip or also of the stalling torque while in operation entails much more equipment, but is also required only on very rare occasions.

The invention will be described with reference to the drawings.

FIG. 1 shows the circulating pump with a motor shaft which is axially slidable during operation;

FIG. 2 shows a pole ring axially slidable on the shaft during standstill only by means of a cam;

FIG. 3 shows a housing construction with inclined slotted guides for axial displacement of the entire drive assembly relative to the pump housing;

FIG. 4 shows a housing construction with axial displacement of the driving assembly by means of a set screw;

FIGS. 5*a* and 5*b* show a magnetic coupling in accordance with the invention with a magnetic shunt which is adjustable in azimuth;

FIG. 6 shows another form of magnetic coupling with a magnetic shunt adjustable in azimuth;

FIG. 7 shows a permanent magnetic pole ring having a disc with soft iron segments arranged at its axial end;

FIG. 8 shows a permanent magnetic pole ring with circumferentially slidable soft iron pieces;

FIG. 9 shows a permanent magnetic pole ring with series connected axially magnetized spherical segments.

FIG. 1 shows a centrifugal pump in accordance with the invention, in section. The rotor **2**, which forms a unit with a soft iron pole ring **3**, rotates in the pump housing **1**. The soft iron core of the pole ring **3** is enclosed by a copper shell **4**, which serves simultaneously the purpose of producing eddy currents and of providing protection for the soft iron pole ring against corrosion. The motor housing **6** is secured to the pump housing **1** via a moulded rubber ring **5** which provides a positive connection and a measure of sound proofing.

The motor housing **6** contains a motor whose armature **9** is supported in the end plates **7** and **8**. The end plates are provided with ribs which positively locate the motor centrally in the motor housing **6**.

The concave pole ring **12** is built up of permanent magnet segments and is driven by the armature **9** via the shaft **13**. The ball bearing **14** is slidably arranged in the bushing **15** of the end plate **8** and is biased towards the motor by the coiled spring **17**. By means of a distance ring **17** the inner race of the ball bearing **14** is positively held on the shaft **13**. The ball bearing **18** is also supported in the bushing **19** of the end plate **7** so as to be slidably displaceable with the outer ring. The outer ring is positively secured to the screw **21** by a cup shaped intermediate member **20** by means of securing means **22**. A screw **21** has a collar **23** which can be fixed axially by inserting annular shims **24**. In the position shown the air gap between the separating shell **25** and the concave pole ring **12** is at its narrowest. If the screw **21** is turned outwards, the spring **16** causes displacement of the armature-pole ring unit **9**, **12** whereby the air gap between the inner shell **25** and the pole ring **12** is increased. The greater the air gap is made, the greater becomes the slip. It has been found that the largest air gap at which the runner **2** still rotates in a stable manner, the speed of the pole ring-runner unit **2,3** drops to approximately one-third of the nominal speed, whereby the hydraulic power of the pump is reduced to one twenty-seventh whilst the power required of the motor is reduced to one-ninth. In this way a significant saving in electricity cost is achieved. The motor is cooled by means of a fan ring **26**, which is attached to the soft iron return path cap **27** of the pole ring **12** and forms a gap **28** with the motor housing **6**. Cooling air enters at **29** and is discharged through the punched apertures **30**.

The armature **9** is so associated with the stator **6** that it lies flush in the stator when the shoulder **23** abuts the screw **21**. As the coupling is reduced, the armature **9** is displaced out of its stator **6**.

FIG. 2 shows a different solution in which the distance of the outer pole ring **12**, from the separating shell **25** is variable via a hub **33** which is slidably displaceable in an axial direction on, and securable to, the motor shaft **34**. Adjustment in the axial direction is accomplished by a cam **35** which slides in an elongated hole **36**. The pole ring is secured by means of set screws **37**. By contrast with the embodiment shown in FIG. **1**, this device can only be adjusted during standstill.

FIG. 3 shows a further embodiment of the invention. A flange **37** in which the entire motor housing **38** is axially displaceable is secured to the pump housing **1**. Axial adjustment is accomplished by slight tilting of the motor housing **38** in the

slotted guides 39, and fixing by tightening up the screws 40. As in the case of the embodiment shown in FIG. 1, the axial distance can, if desired, be varied whilst the pump is running.

FIG. 4 shows a further embodiment in which the motor 41 is suspended in two rubber rings 42 and 43 which are secured to the motor housing 44 at its outer periphery in axially fixed relationship and exert an axial force in the direction of the arrow 45. The adjusting screw 46, which transmits its force via the elastic rubber element 47 to the motor 41 so as to prevent the transmission of sound from the body, acts against this axial force. As in the case of the embodiment shown in FIG. 1, the axial distance can here also be varied whilst the pump is running.

FIG. 5*a* shows diagrammatically the principle of construction of a cylindrical coupling in which the permanent magnets 50 of the inner pole ring are arranged between the inner pole ring 52 and the outer pole ring 53 transversely to the direction of the radial lines of force 51. The iron segments 54 which lie between the magnets 51 serve as pole shoes. Starting from their outer surface 55 the lines of force extend across the air gap 56 to the outer pole ring 53 which is made up in the form of a squirrel cage rotor of soft iron 59 and conductor rods 60 which are short-circuited together at their axial ends. The magnitude of the active magnetic field in the air gap 56 can be influenced via the rear side 57 of the iron segment 54, in that by varying the position of the iron parts 58 which are interconnected by a magnetically ineffective ring (not shown) in azimuth, a magnetic shunt between adjacent iron segments 54 and 54' can be created.

FIG. 5*b* shows the same construction of the inner pole ring, whereas the outer pole ring 53' consists of an iron ring and radially magnetized magnets 12 secured therein.

FIG. 6 shows a construction in which the iron parts 61 which are displaceable in azimuth serve the purpose of adjustably improving the return path of the magnetic lines of force, the return path being provided via the thin walled iron cylinder 62 in an unsatisfactory manner, so that the effect of the force on the rotor 63 in the position shown is at a maximum, and in a position displaced by half a pitch at a minimum. In this construction a hysteresis material was chosen for the rotor 63 which has only secondary produced magnetic poles 66, so that above a maximum torque the couplings slip without vibration, whereas below that maximum torque it transmits the torque without slip.

FIG. 7 shows an axial plan and an axial plan as seen from the opposite direction as well as an axial section of a pole ring for a coupling with a spherical air gap. The magnets 70 have iron segments 71 disposed between them which are enlarged by soft iron spherical segments 72 towards the air gap. On the rear side a ring 73 made of nonmagnetic material is provided in which soft iron pieces 74 are inserted whose span corresponds to approximately four-fifths of the pitch 75. In the sector 76 these soft iron pieces magnetically shortcircuit adjacent iron segments, whilst they each register with a soft iron segment 71 in the sector 77, so that the magnetic short circuit disappears.

FIG. 8 shows a like embodiment, in which however a ring 80 is associated with soft iron pieces 81 which again connect adjacent iron segments 71 or the neutral central zones of adjacent magnets 70/70' with each other.

FIG. 9 shows diagrammatically and partly in section an outer pole ring consisting of a soft iron body 90 in which a first plurality of radially magnetized magnets 95/95' is secured. In the so formed spherical cup a further plurality of axially magnetized spherical segments 91/91' is provided which is collected together via nonmagnetic segments 92 into a pivotable spherical cup. By pivoting this spherical cup by half a pitch as shown at 94/94' the magnetic fields of the magnetic segments 90 and 91 are partially neutralized.

I claim:

1. A motor driven centrifugal pump whose runner forms a unit enclosed in a pump housing, with a soft magnetic pole ring, the wall of the pump housing adjacent the pole ring consisting of magnetically permeable material and a permanent magnet pole ring driven by the motor and arranged to transmit the motor torque to the first pole ring with little operational slip being arranged adjacent and outside this wall, characterized in that means are provided for reducing the flux passing through the magnetically permeable separating wall, thereby the slip is increased.

2. A centrifugal pump according to claim 1, characterized in that the magnetic air gap is variable by axial displacement of one pole ring (12) relative to the other.

3. A centrifugal pump according to claim 2, characterized in that the pole ring (12) is arranged so as to be displaceable relative to the shaft (13) and axially securable.

4. A centrifugal pump according to claim 2, characterized in that the pole ring (12) forms a unit with the shaft (13) and the armature (9) and that this unit is arranged so as to be axially displaceable.

5. A centrifugal pump according to claim 4, characterized in that the shaft is supported in ball bearings and that the bearing (14) facing the pump housing is spring biased by the spring (16) towards the pole ring (6'), whereas the second ball bearing (18) is axially adjustable by positively connected elements (18, 21).

6. A centrifugal pump according to claim 4, characterized in that the motor armature (9) is disposed symmetrically to the central rotational plane of the stator (6'), when the air gap of the pole ring (12) is at a minimum, whereas the motor armature is displaced from the optimum central position as the air gap increases.

7. A centrifugal pump according to claim 2, characterized in that the motor housing (38) is arranged so as to be displaceable relative to the pump housing (1).

8. A centrifugal pump according to claim 1, characterized in that the first pole ring (3) which is integral with the pump runner (2) consists of soft iron and carries a surface layer (4) of a material of high electrical conductivity.

9. A centrifugal pump according to claim 8, characterized in that the layer of the material of high electrical conductivity is copper and that it also protects the side of the rotor (3) facing the separating wall (27).

10. A centrifugal pump according to claim 1, characterized in that the first pole ring (3) which is integral with the pump runner (2) consists of a magnetic material whose coercive force is so small that at least during acceleration when starting up slip occurs between the first and the second pole ring (12).

11. A centrifugal pump according to claim 1, characterized in that a ring (73, 80) of magnetically nonconductive material is associated with bodies (58, 74, 81) of soft iron, whose circumferential span is smaller than the pitch (75) between adjacent magnet poles and that the ring (73, 80) can be pivoted through an angle corresponding to approximately half a pole pitch (75).

12. A centrifugal pump according to claim 10, characterized in that the magnet poles (54, 71) consist of soft iron and that the permanent magnets (50, 70) are magnetized in the circumferential direction.

13. A centrifugal pump according to claim 1, having a pole ring with permanent magnets, one pole face of the magnets being arranged facing the air gap and the other pole face facing a magnetic return path ring, characterized in that the magnetic return path ring (62) has a number of regions (61) of high magnetic conductivity equal to the number of poles, the said regions being arranged for displacement in azimuth in such a way that in one terminal position thereof they are disposed between two adjacent poles and there form the magnetic return path between adjacent poles, whereas in their other terminal position they register with the poles and thus do not present a return path.

14. A centrifugal pump according to claim 1, characterized in that the pole ring carrying permanent magnets (91, 95) consists of two rings arranged within each other or adjacent each other and having the same number of poles and in that the rings are arranged for relative displacement by approxi-

mately half a pole pitch, so that in one terminal position the magnetic fluxes are additive, whereas in the other terminal position they partially neutralize each other.

15. A motor driven centrifugal pump whose runner forms a unit enclosed in a pump housing, with a soft magnetic pole ring, the wall of the pump housing adjacent the pole ring consisting of magnetically permeable material and a permanent magnet pole ring driven by the motor and arranged to synchronously transmit the motor torque to the first pole ring, characterized in that means are provided for reducing the flux passing through the magnetically permeable separating wall, whereby the stalling torque is reduced.

16. A centrifugal pump according to claim 15, characterized in that the magnetic air gap is variable by axial displacement of one pole ring (12) relative to the other.

17. A centrifugal pump according to claim 16, characterized in that the pole ring (12) is arranged so as to be displaceable relative to the shaft (13) and axially securable.

18. A centrifugal pump according to claim 17, characterized in that the pole ring (12) forms a unit with the shaft (13) and the armature (9) and that this unit is arranged so as to be axially displaceable.

19. A centrifugal pump according to claim 18, characterized in that the shaft is supported in ball bearings and that the bearing (14) facing the pump housing is spring biased by the spring (16) towards the pole ring (6'), whereas the second ball bearing (18) is axially adjustable by positively connected elements (18, 21).

20. A centrifugal pump according to claim 18, characterized in that the motor armature (9) is disposed symmetrically to the central rotational plane of the stator (6'), when the air gap of the pole ring (12) is at a minimum, whereas the motor armature is displaced from the optimum central position as the air gap increases.

21. A centrifugal pump according to claim 16, characterized in that the motor housing (38) is arranged so as to be displaceable relative to the pump housing (1).

22. A centrifugal pump according to claim 15, characterized in that the first pole ring (3) which is integral with the pump runner (2) consists of soft iron and carries a surface layer (4) of a material of high electrical conductivity.

23. A centrifugal pump according to claim 22, characterized in that the layer of the material of high electrical conductivity is copper and that it also protects the side of the rotor (3) facing the separating wall (27).

24. A centrifugal pump according to claim 15, characterized in that the first pole ring (3) which is integral with the pump runner (2) consists of a magnetic material whose coercive force is so small that at least during acceleration when starting up slip occurs between the first and the second pole ring (12).

25. A centrifugal pump according to claim 15, characterized in that a ring (73, 80) of magnetically nonconductive material is associated with bodies (58, 74, 81) of soft iron, whose circumferential span is smaller than the pitch (75) between adjacent magnet poles and that the ring (73, 80) can be pivoted through an angle corresponding to approximately half a pole pitch (75).

26. A centrifugal pump according to claim 24, characterized in that the magnet poles (54, 71) consist of soft iron and that the permanent magnets (50, 70) are magnetized in the circumferential direction.

27. A centrifugal pump according to claim 15, having a pole ring with permanent magnets, one pole face of the magnets being arranged facing the air gap and the other pole face facing a magnetic return path ring, characterized in that the magnetic return path ring (62) has a number of regions (61) of high magnetic conductivity equal to the number of poles, the said regions being arranged for displacement in azimuth in such a way that in one terminal position thereof they are disposed between two adjacent poles and there form the magnetic return path between adjacent poles, whereas in their other terminal position they register with the poles and thus do not present a return path.

28. A centrifugal pump according to claim 15, characterized in that the pole ring carrying permanent magnets (91, 95) consists of two rings arranged within each other or adjacent each other and having the same number of poles and in that the rings are arranged for relative displacement by approximately half a pole pitch, so that in one terminal position the magnetic fluxes are additive, thereas in the other terminal position they partially neutralize each other.

* * * * *