United States Patent [19]

Bénezéch

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[45] **Sept. 4, 1973**

[54] **DIRECT CURRENT TRACTION MOTOR**

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[52] **U.S. Cl.** **310/181,** 310/154

[51] **Int. Cl.** **H02k 23/02**

[58] **Field of Search** 310/181, 182, 183, 310/154, 155, 225, 179, 180, 68

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Attorney—Arnold B. Christen et al.

[57] **ABSTRACT**

A direct current traction motor comprising a rotary armature consisting of a stack of slotted magnetic plates surrounded with a gap by a composite multipolar induction assembly wherein each pole comprises a core-mounted induction coil and a permanent induction magnet, the respective inductors of the poles thus forming two sets spaced equidistantly around the armature, either in fixed axially aligned relationship or in variable angular relationship as between one set and the other, and the axial distance between the coil and the magnet at each pole bearing a predetermined relationship to the gap between the armature and induction assembly.

14 Claims, 5 Drawing Figures

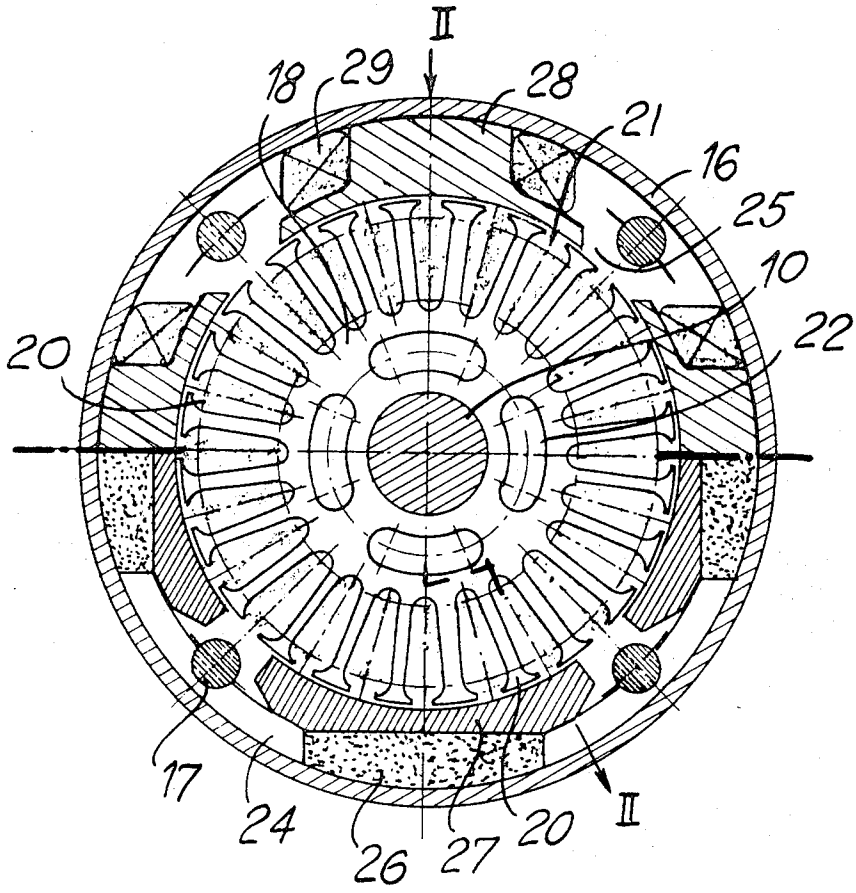
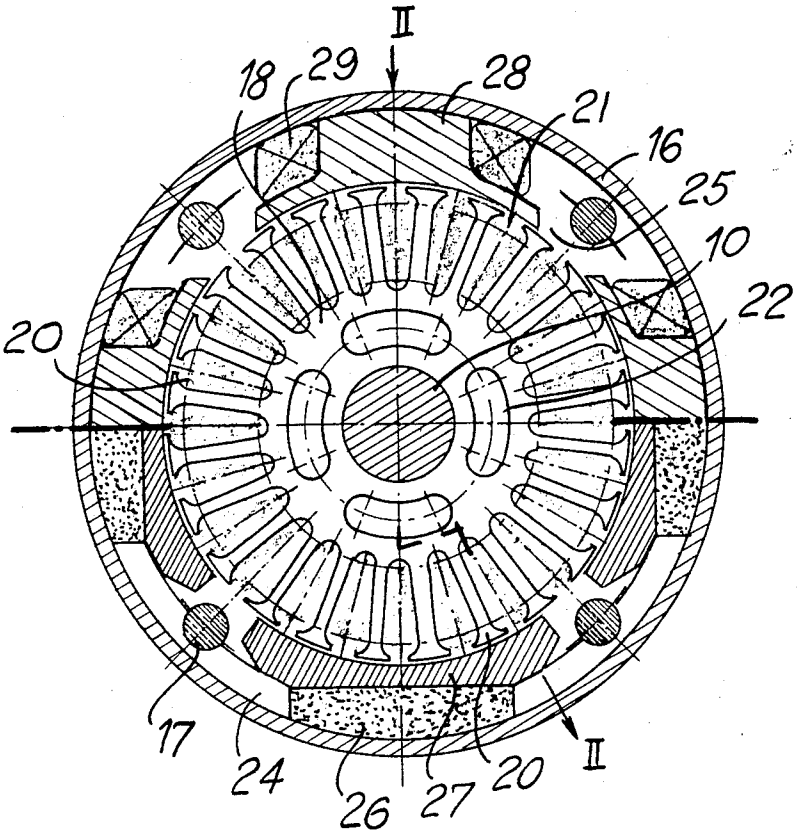


Fig. 1.



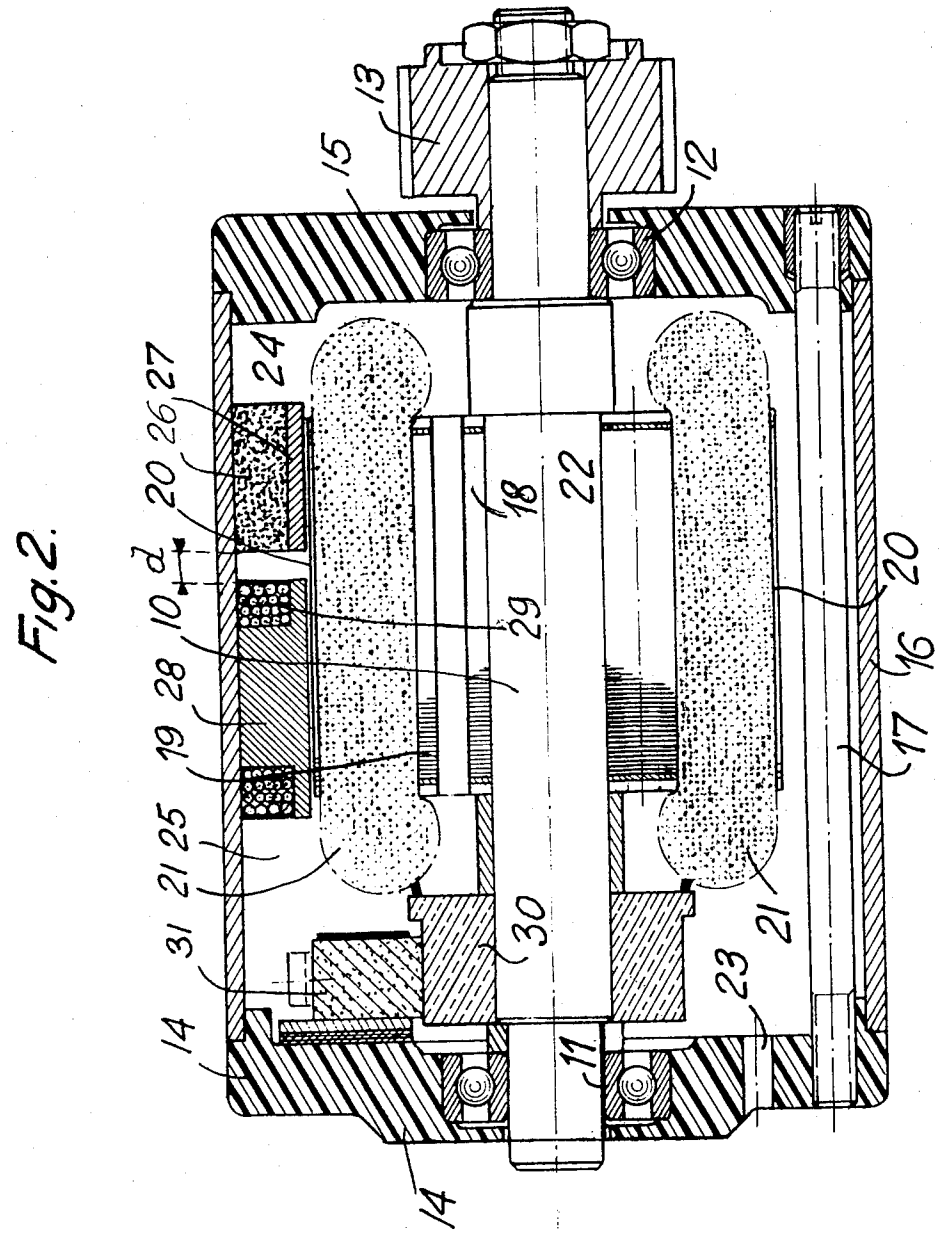

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Fig. 2.

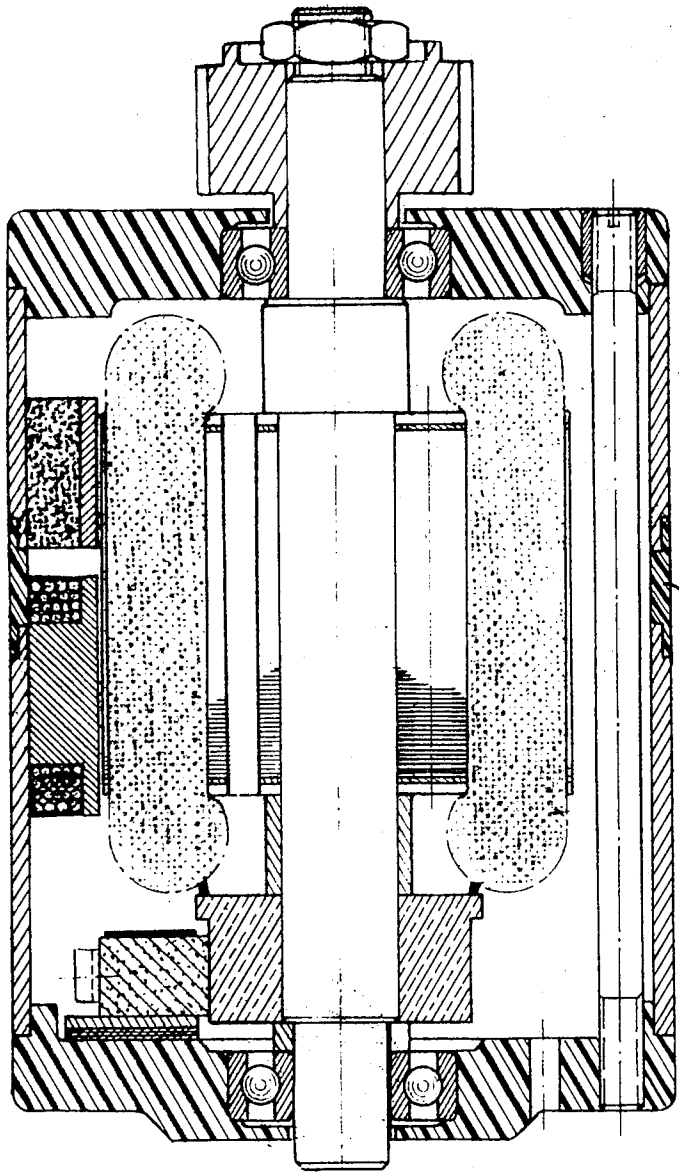


Fig. 2a.

Fig.3

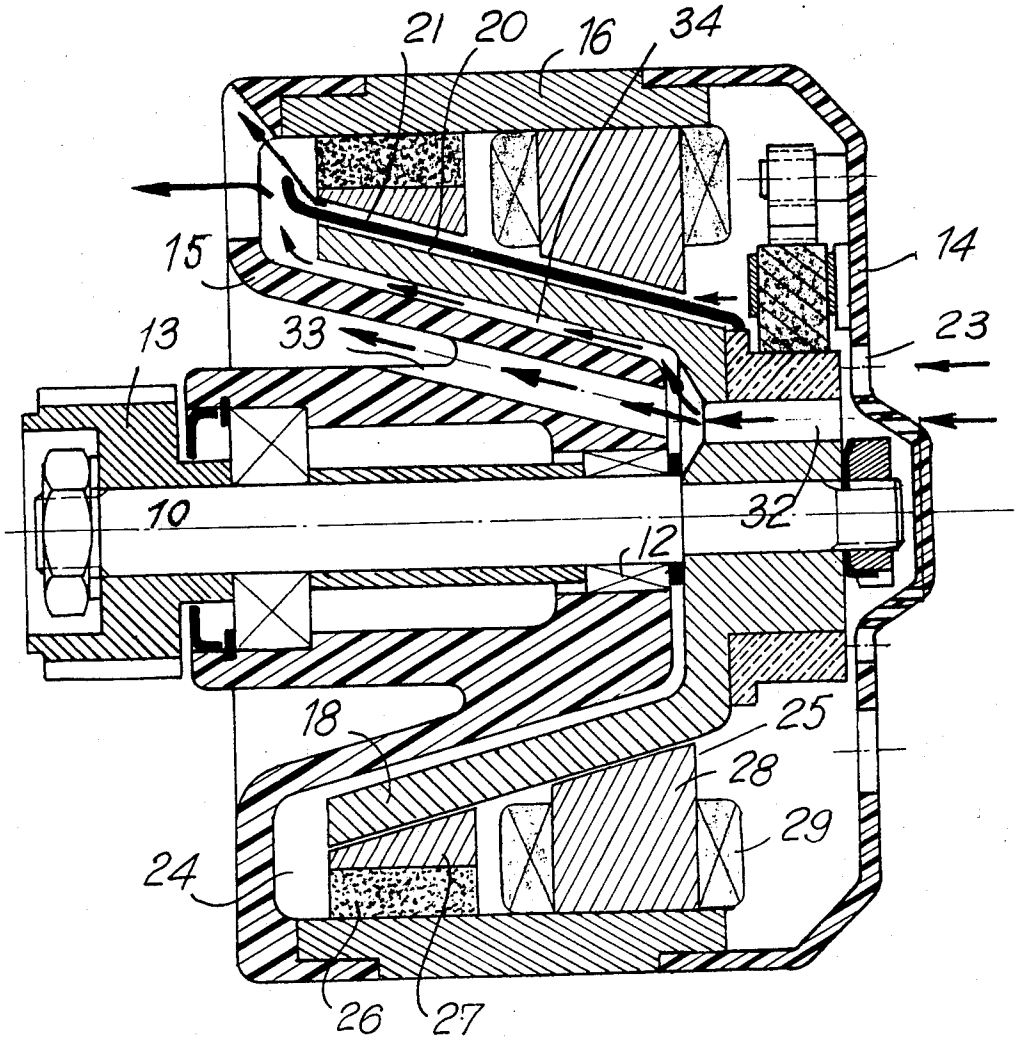
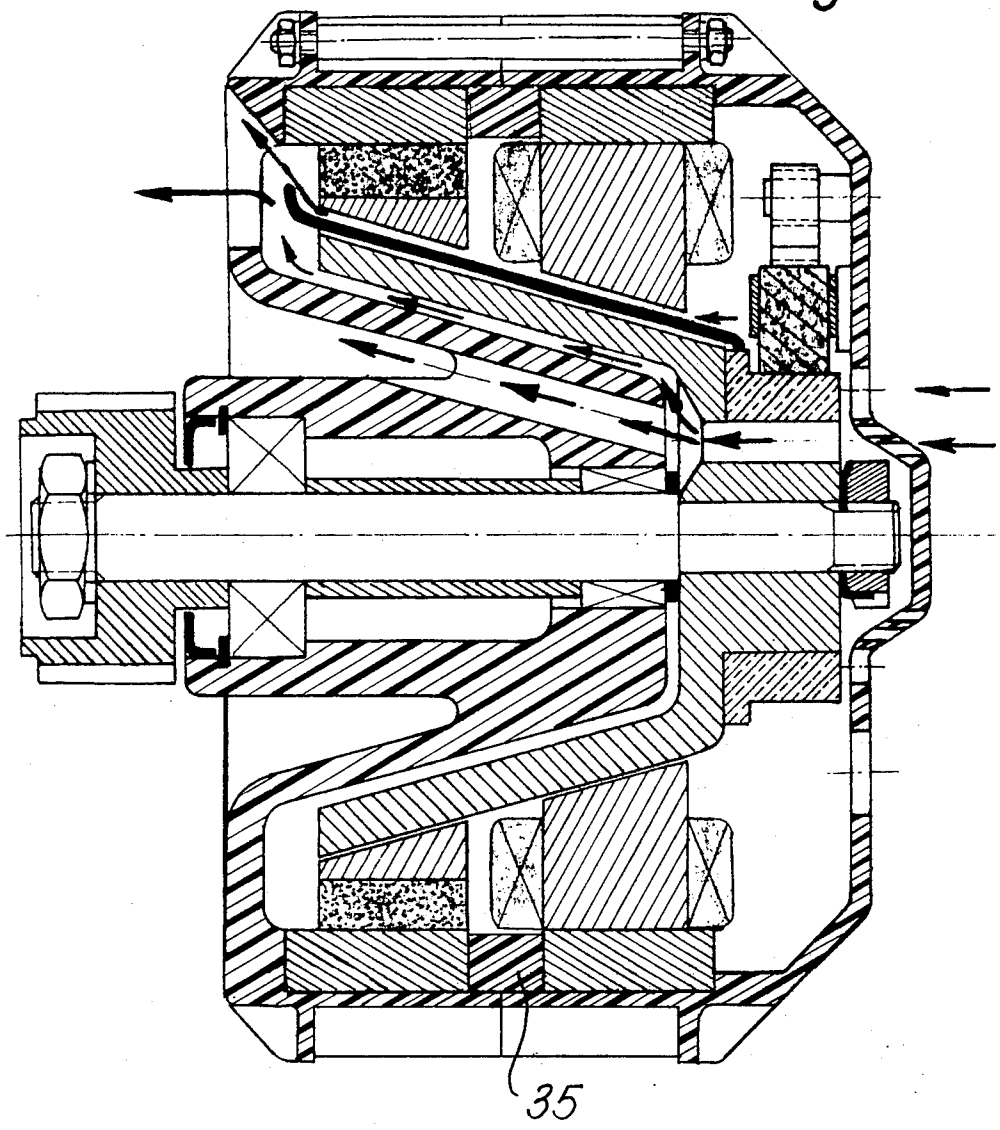


Fig 3a



DIRECT CURRENT TRACTION MOTOR

FIELD OF THE INVENTION

Vehicles with independent power sources are generally propelled by internal combustion engines or by diesel engines. In the course of recent developments in road transport, serious objections have been raised to this type of propulsion, which causes substantial pollution of the air owing both to the release of oxides of carbon and nitrogen in the waste products of the combustion and to the excessive production of fumes. Another source of objection is the excessive nuisance caused by the noise by heavy goods vehicles equipped with diesel engines.

Endeavours have been made by active and laborious research to remedy these very serious drawbacks, but it is by no means certain that it will be possible to achieve this object efficiently without lowering the known high qualities of current internal combustion engines.

Thus, in view of the justified requirements of the public services, designers are pushed towards the development of more silent vehicles which are equipped with power sources in which the main defect of atmospheric pollution is absent.

The electric car, which meets these requirements, has been known for a long time, and many embodiments of this vehicle have been made since the start of this century. However, it has never been commercially successful owing to the excessive weight and the bulk of normal batteries (lead or alkaline) and the necessity of recharging these batteries at very frequent intervals.

The substantial progress made during the last few years in the field of electrochemical generators, such as fuel cells, zinc-air cells, sulphur-sodium cells, etc., removes these various drawbacks, and the moment seems near for the distribution on the market of electric vehicles with high performance.

It therefore appears necessary to consider other features which are necessary for such electric vehicles, and particularly traction motors operating with direct current, and this is the subject of the present invention. For this purpose it is necessary to realise d.c. motors in which the commutators rotate at high speed and with high yield, i.e., a large part of the induction field is created by permanent magnets. However, in order to obtain a large torque during starting and at low speeds, the field magnet must be equipped with a series winding, whilst the control of the number of turns in the region of high speeds requires the provision of a separate or shunt winding.

BACKGROUND OF THE INVENTION

The d.c. motor according to this invention consists substantially of:

- a revolving central armature comprising a stock of slotted magnetic plates;
- an induction assembly with at least two equidistantly spaced poles wherein each pole consists of an induction coil wound on an iron core, and a permanent induction magnet, particularly flat-shaped and of ferrite, wherein these two induction elements are arranged at the same angular offset, either permanently or not, relative to the armature and are separated one from the other by a distance which is larger than twice the gap between the armature and the induction assembly.

SUMMARY OF THE INVENTION

According to a further feature of the invention, in a motor with cylindrical or conical coaxial armature and induction assembly, in every pole, the induction coil and the permanent induction magnet are aligned in the direction of generatrices either with or without the possibility of displacing the permanent induction magnets angularly by a cylindrical or conical ring or crown coaxial with the armature and having an adjustable angular position.

According to the invention, in a flat motor with axial gap, the armature is reduced to an insulating disc carrying conventional or printed conductors, and the induction assembly is formed on either side of this disc by two circular supports, concentric to the axis of the disc and carrying, one the induction coil and the other the permanent induction magnets, wherein the two induction members of each pole are mounted on a same radius, possibly with means for carrying out the angular displacement of the supports of the permanent induction magnets relative to those of the induction coils.

According to a further feature of the invention each induction winding comprises a winding in series with a shunt winding or not.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features of the invention will be apparent from the following description referring to the accompanying drawings, showing two exemplified embodiments of the invention, and in which:

FIG. 1 is a transverse cross-section of a d.c. traction motor according to the invention with cylindrical armature and induction assembly, with fixed poles in which the upper half section is taken at the level of the wound induction coils and the lower half section at the level of the permanent induction magnets;

FIG. 2 is a longitudinal cross-section of the same motor along the line II—II in FIG. 1;

FIG. 2*a* shows a modification;

FIG. 3 is a longitudinal cross-section of a motor according to the invention with conical armature and induction assembly, in which the poles are fixed; and

FIG. 3*a* again shows a modification.

Prior to describing the detailed construction of these motors it will be stated how the applicants have been led to this type of motor with mixed induction elements.

Let us consider for example the most usual case of a motor with cylindrical, coaxial armature and induction element.

The most simple arrangement which comes to mind for combining in such a motor the two types of inductors is to use permanent magnets as poles and to wind round each of them both series and shunt windings. The applicants have abandoned consideration of this arrangement because it is difficult, if not impossible, to counteract the demagnetisation, because the magnets to be chosen for reasons of permeability are permanent metal magnets, and on the other hand the reluctance of such magnets is not sufficiently weak to provide sufficient inductors.

Under these conditions one is led to alternate around the armature wound inductors and permanent induction magnets, and this solution proposes itself in a simple manner to a man skilled in the art. It is now possible to use ferrites for the permanent induction magnets and

the problem of de-magnetisation no longer arises. However, it is now necessary to counteract the asymmetry and the modulation of the induction fields which are created and which become apparent by rattling of the brushes, vibration and an aggravation iron losses. These are unacceptable drawbacks which are extremely difficult to overcome and the applicants have, therefore, also abandoned this second arrangement.

For this reason and taking a non-conventional and, therefore, surprising course, the applicants consider it preferable in these motors to split each each pole longitudinally relative to the generatrices into two elements, which two elements correspond respectively to the two types of inductors. The applicants also regard it as necessary, for the higher performance of a traction motor within inductors constructed in this manner, to use the other essential features described above.

It should be noted that by means of the splitting of the poles along the generatrices, the use of ferrite magnets remains, but there no longer exists asymmetry of the fields, since every armature section contains in theory the sum of the generated magnetic fluxes, and the number of ampere-turns in series and in shunt remains normal to produce good operation.

DESCRIPTION OF SPECIFIC EMBODIMENT

FIGS. 1 and 2 show an example of a motor with a coaxial, cylindrical armature and induction assembly according to the invention. This motor is mounted on a shaft **10** running at its ends in ball bearings **11** and **12**. On the other side of the ball bearing **12**, the shaft carries a gear **13** for the transmission of its movement. This mechanical arrangement is not essential and may be modified in any known or suitable manner, according to the product specification and the maximum speed in r.p.m. of the motor.

The frame of the motor consists of two lateral side pieces **14** and **15** which are connected by a housing of magnetic iron or steel **16**. The rigidity and stability of this frame are reinforced by amagnetic stays such as **17**.

The cylindrical armature **18** of the motor comprises a longitudinal stack of magnetic plates **19** with peripheral slots **20** containing the insulated conductors of an induction winding **21**. This armature has longitudinal channels **22** and the side pieces of the frame are provided with holes **23** to ensure cooling by means of circulating air.

According to the principle of the invention the inductor is formed from a certain number of poles distributed regularly about the armature, for example four, wherein each pole is split into two elements aligned along their generatrices, one permanent induction magnet **24**, and one induction coil **25**. Each induction magnet **24** comprises a flat magnet **26**, preferably of ferrite, fixed on the frame, more particularly by gluing, and terminated on the side of the gap by a polar mass **27** (FIG. 1), of soft iron, or a soft magnetic material with minimum reluctance so as to conduct the flux of the magnet well in a radial direction.

Each induction coil **25** includes a core **28** of a high grade soft magnetic material in which the useful longitudinal cross-section in the shape of a T is greatest. In order to reduce induction and inhibit saturation. The core is fixed to the frame and has on the side of the gap in cross-section a pole piece which channels the force lines and distributes them along the armature, as shown in FIG. 1, wherein this cross-section has the shape of a T. The winding **29** of this inductor may be a compound winding, i.e., a series winding and a separate parallel winding, i.e., a series winding and a separate parallel winding, or more simply a single series winding (vehicles with low maximum speed).

In the embodiment shown in FIGS. 1 and 2, the two induction elements of each pole are assumed to be fixed relative to each other, and relative to the cylindrical periphery of the armature. As shown in FIG. 2, the gap *d* between them is clearly larger than double the gap between inductor and armature.

The motor is also equipped (FIG. 2) with a commutator **30** on which rests brushes such as **31**. In view of the fact that the action of the permanent magnet inductors will usually be the most important, these brushes are adjusted on the centre line and may be made of a material with low electrical resistance, for example of silver.

The function and the adjustment of the motor just described are as follows.

The configuration of the magnetic lines of force follows well known theories relating to d.c. motors with induction coils or magnets, i.e., they start at one pole, pass through the gap into the armature, travelling along a certain number of sections of the winding, and continue to the adjacent pole after passing a second time through the gap, wherein the lines of force are closed by the frame of the motor.

It is obvious that, as with all electromagnetic machines, this motor has magnetic losses which limit its performance. If we consider the lines of force starting from the induction coil, they have little chance of being directed towards the magnet because the latter is of ferrite and has a permeability which is equal to unit value, and does not form a preferential path for the magnetic flux. The magnetic losses of the induction coil into the magnetic are, therefore, insignificant.

If we consider the lines of force coming from the magnet we could ask if these could be shifted towards the core of the induction coil. Two loss paths may be envisaged in the two cases of possible operation, i.e., with and without current in the induction coil.

In these two cases, the direct passage of the lines of force from the magnet to the core of the induction coil is comparatively rare in view of the distance separating these, compared with the gap. a. In the case of as non-energised induction coil, a certain proportion of the lines of force coming from the magnet may penetrate to a slight depth into the armature and return to the inductor after passing twice across the gap. These lines of force have passed through the armature in the gaps between the slots, without traversing all sections of the winding of the armature, i.e., with less efficiency, but this path has a reluctance which limits the magnitude of these losses (leakages); in fact, these lines of force must pass through the armature in the direction of the stack of plates. b. The induction coil is energised and since it creates a field in the same direction as the magnet, this field opposes magnetic leakges, and these are therefore further reduced compared with the preceding case.

The motor under consideration is a multipolar motor (it is assumed to be a quadripolar motor) having a main field coming from the permanent magnets. At a given supply voltage, this motor has, therefore, a stable speed and a constant torque. In certain embodiments, the speed may reach a nominal value near 5,000 r.p.m. Since this motor is assumed to have a compound induc-

tion coil, the series winding brings about the advantage of a high torque during starting and generally at low speed, whilst the separate parallel winding, which is independently controlled, makes it possible to adapt the speed in the range of the nominal value.

In practice, the motor will function with a permanently connected series excitation, and a separate excitation which is variable from zero to maximum.

Generally, the speed control will be effected in the following manner:

Up to 60 percent of the top speed, the variations of the speed will be produced by acting on the voltage or the armature current. It is possible for the main current to be chopped, for example by an electronic device of the "chopper" type in which either the frequency or the width of the pulses are varied. One type of such apparatus is described in the "SCR Manual" published by the General Electric Company, pages 237 – 239, wherein a Jones SCR Chopper is explained. From this speed range of about 60 percent, the adjustment up to maximum speed is made by controlling the separate winding, by reducing the value of this field for increasing the speed.

The series winding is of considerable importance because it provides an important torque in the difficult conditions for the vehicle: starting on level ground or uphill, travelling over ramps, which corresponds to operation in low rotational ranges. As the speed rises the counter-electromotive force rises very rapidly, according to one of the known properties of motors with magnets. It follows that as the consumption current drops, the field of excitation caused by the series winding decreases to a point where it is negligible, which is interesting for the stability of the speed and for the output of the motor. At the same time, this phenomenon reduces fatigue of the commutator and of the brushes by suppressing arcing. Examination of the operational characteristics discloses also a further phenomenon: the voltage drops due to the armature reaction are reduced.

As d.c. motors in general, this motor may be braked in the usual manner. a. By a rheostatic process, by making the motor operate on a resistance, with or without the use of induction coils. b. By recovery, by switching on the d.c. generator, if this generator is reversible.

It can be deduced, from these various properties, what happens in the course of an accidental failure of the induction coils, either by rupture of their windings or by an incident at the level of commutation.

If the vehicle is travelling normally, the speed will be stabilised at maximum speed without obstruction if the field of the magnets is maintained; braking, either rheostatic or by recovery may be carried out normally. This property is a very important safety factor for the vehicle.

The output of the motor according to the FIGS. 1 and 2 may be improved by arranging the induction magnets and the induction coils on different generatrices for each pole, i.e., with a different angular offset about the armature for each type of inductance.

More generally, the magnetic inductors will be mounted on an inner cylinder coaxial with the frame and adapted to rotate relative thereto in order to change the distance between the magnetic inductors and the induction coil. Thus, when the induction coils are in use (series and parallel inductors) the magnetic inductors are aligned and the offset has the optimum value for the induction coils. When the induction coils are in substantially reduced use (only the series remains at low intensity) the movement of the magnetic inductors is carried out relative to the brushes to provide optimum offset for this case, i.e., substantially on the neutral line for the brushes.

In the case where a motor, such as that of FIGS. 1 and 2, has such proportions that it must be anticipated that the magnetic leakages between the inductors are too large, this drawback may be overcome in the following manner:

At the centre of the armature opposite the interval between the two inductors of the same pole, insulating foils are introduced which separate the armature iron into two iron parts which are distinct in the longitudinal direction, whilst the winding remains the same, thus the lines of force coming from each type of inductor remain in the corresponding part of the armature, thereby avoiding a leakage from one inductor to the other through the armature iron.

It is also possible to reduce magnetic leakages between two inductors without modifying the magnetic armature circuit, i.e., leaving it as one whole but introducing into the outer frame an amagnetic ring opposite the interval between the two inductors of the same pole, thereby preventing the return of the lines of force between these two inductors.

This may be realised with a cylindrical or with a conical motor (FIG. 3*a*), preferably with a ring of aluminum alloy 35 or 36 (FIG. 2*a*).

The choice of any one of these two solutions will depend generally on the geometry of the motor.

Furthermore, and as already outlined above, the motor may be further simplified by designating it without a separate parallel winding, in which case the general properties are maintained, although slightly diminished, and the supplementary speed control in the high speed ranges is omitted.

The choice between the arrangement outlined above will depend naturally on the type of vehicle for which the motor is intended to be used (motorcycle, urban motorcar, road motorcar, etc.).

The nature of the vehicle and its arrangement may require the use of a modification of the motor with conical armature and inductors, as mentioned hereinbefore, and as shown for mixed induction motors in cross-section in FIG. 3.

In this Figure, the same reference numerals are used as in FIGS. 1 and 2 in order to mark the same elements. Substantially, this conical arrangement will provide the following advantages:

A substantial weight reduction of the armature, more particularly with regard to the iron; reduction in weight, in volume, in iron losses, in Joule losses and in mechanical losses. The ventilation may be improved by means of channels 32, 33 and 34; the arrows indicate the flow paths for the circulating cooling medium.

Finally, it should be noted that, as already pointed out above, the motor according to the invention may be constructed as a flat motor, but such a motor would have to be controlled by a "chopper," specially constructed for a motor with particularly low self-induction.

We claim:

1. A direct-current tractor motor comprising a rotatable armature composed along its entire length of magnetically permeable material, a series of multipolar in-

ductors, each of the poles of said inductors including a first and second assembly, said first assembly comprising a core of magnetically permeable material and a coil, said second assembly comprising a ferrite magnetic material, a frame to support said armature for rotation and to mount the respective first and second assemblies of each of said inductors in alignment with each other in a direction transverse to the direction of rotation of the armature and disposed to establish a magnetic path between the respective first and second first and second assemblies of each pole through said armature.

2. A motor according to claim 1, wherein at each pole, the induction coil and the permanent induction magnet are aligned in the axial direction.

3. A traction motor according to claim 2, wherein each permanent induction magnet comprises a flat ferrite magnet fixed on the frame of the motor and terminated at the side of the said gap by a polar mass.

4. A motor according to claim 3, wherein the core of each induction coil has T-shaped longitudinal and transverse cross-sections, whereby to present a wider portion on the side of the said gap.

5. A motor according to claim 1, wherein the armature comprises an insulating disc carrying conductors, and the induction assembly is formed on the respective sides of this disc by two circular supports, concentric with the axis of the disc, and one carrying the induction coils and the other the permanent induction magnet.

6. A traction motor according to claim 1, wherein each induction coil comprises a series winding and a separate parallel winding.

7. A traction motor according to claim 1, wherein the winding of each induction coil is a series winding.

8. A motor according to claim 1, wherein the commutator brushes are set at the neutral line.

9. A motor according to claim 1, wherein the brushes are made from silver or like material having a low electrical resistance.

10. A motor according to claim 1, wherein means are provided for producing an angular displacement of the permanent induction magnets relative to the induction coils.

11. A motor according to claim 10, wherein the permanent induction magnets are mounted on a surface of revolution coaxial with the armature and inside of the frame of the motor, and wherein this surface of revolution has an angular position which may be varied relative to the induction coils fixed on the frame.

12. A motor according to claim 1, wherein the armature iron is divided longitudinally into two parts by means of insulating foils placed opposite the interval between two inductors of the same pole.

13. A motor according to claim 1, wherein the frame of the motor includes a ring of non-magnetic material oposite the interval between two inductors of the same pole.

14. A motor according to claim 1, wherein the speed adjustment is carried out by means of an electronic "chopper" arrangement effective up to approximately 60 percent of the top speed, and by acting on the shunt winding above this percentage.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,757,150

DATED : September 4, 1973

INVENTOR(S) : Jacques H. Benezech

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading, after "Filed Feb. 29, 1972" please insert --Claims Priority of French Appln. No. 71.07.657, filed March 5, 1971--.

Signed and sealed this 29th day of April 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT OFFICE

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