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(71) Applicants
Rolls-Royce and Associates Limited, (Great Britain), PO Box 31, Moor Lane, Derby DE2 8BJ
(72) Inventors
Anthony Norman Claridge
Alfred John Smith
(74) Agent and/or Address for Service
M. A. Gunn, Rolls-Royce Limited, Patents Department, PO Box 31, Moor Lane, Derby DE2 8BJ

(54) Reluctance device

(57) A reluctance device comprises two or more phases (10), each of which has a rotor (11) mounted for rotation within a tubular member (12) and an annular stator (18) positioned externally of the tubular member (12). The rotor (11) and the internal surface of the tubular member (12) are each provided with aligned, axially spaced apart annular arrays of teeth (13, 14, 15 and 16), *the teeth (13 and 14) on the rotor* (11) confronting those on the tubular member (12) in radially spaced apart relationship. The stator (18) encloses a coil (21) which, when electrically energised, creates a plurality of magnetic flux paths (23) each of which extends radially between the rotor (11) and stator (18) *via* the confronting teeth (13, 14, 15 and 16) and the tubular member (12), and axially along both the rotor (11) and the portion of said stator (18) located radially outwardly of the coil (21). The portion of the tubular member (12) intermediate the teeth (15, 16) thereon is provided with a non-magnetic insert (24) in order to resist the axial passage of magnetic flux therethrough.

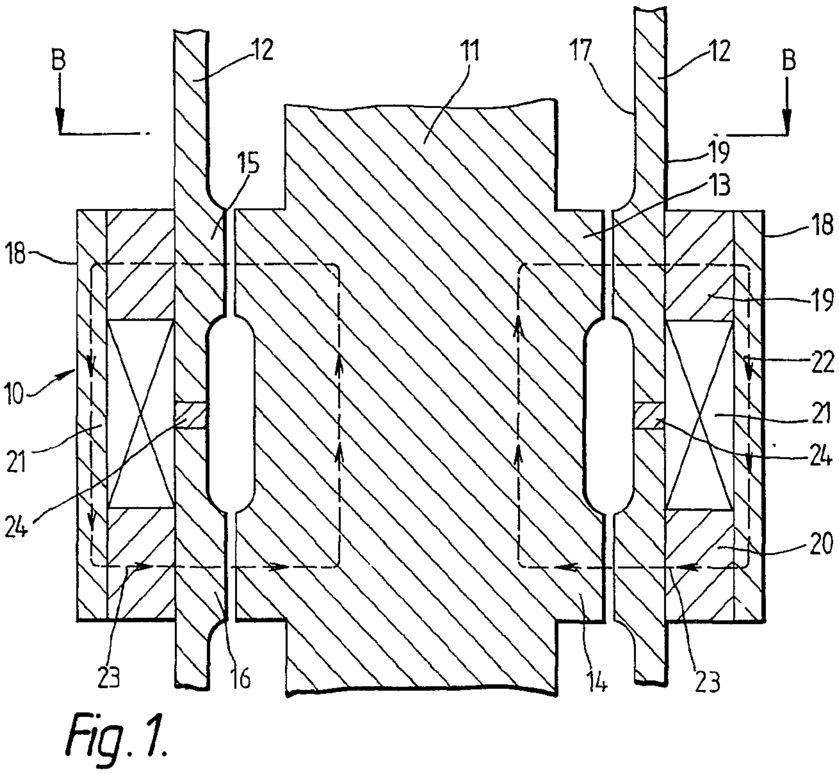

Fig. 1.

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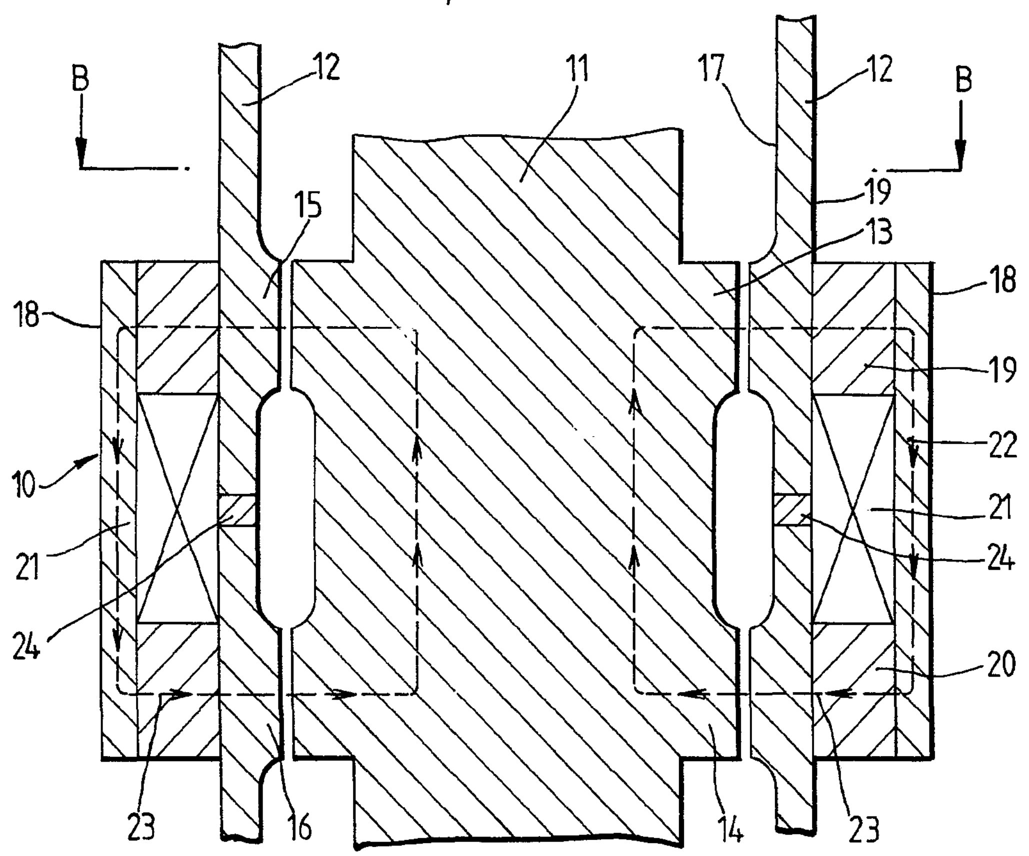
B
12
11
17
12
B
15
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14
23

Fig. 1.

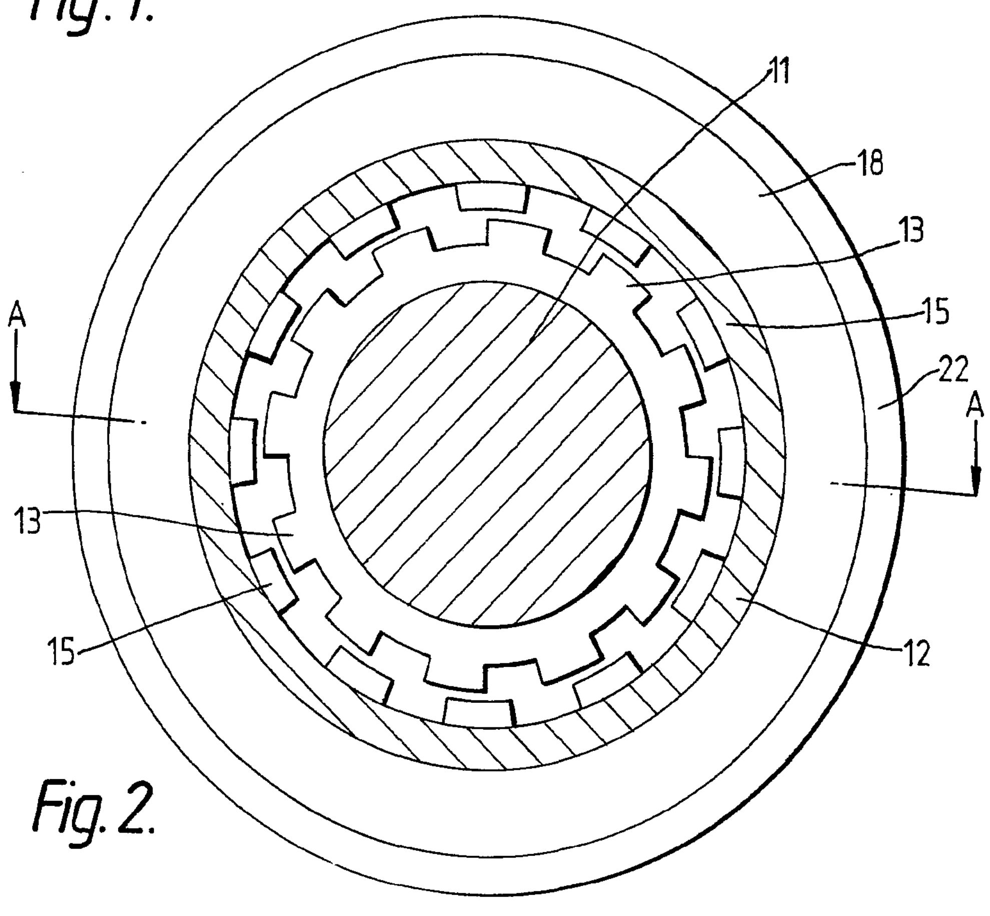
11
18
13
A
15
22
A
13
15
12

Fig. 2.

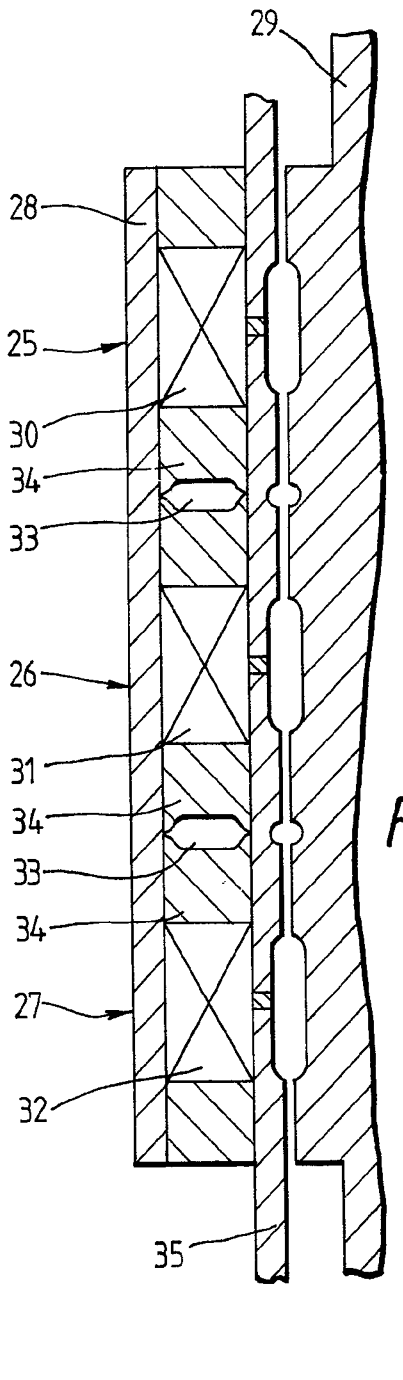

Fig. 3.

SPECIFICATION

Reluctance device

This invention relates to a reluctance device which provides stepwise rotary motion and which has a barrier interposed between the rotor and stator portions thereof.

There are circumstances in which it is necessary to provide rotary motion within an enclosed member, the interior of which is not easily accessible from the exterior thereof. For instance, the control rods of a nuclear reactor are each contained within a tube and are raised and lowered within the tube by means of a screw thread mechanism which is powered by an electric motor. Since the tube interior is exposed to the reactor environment, there are difficulties in locating an electric motor within the tube. One way of avoiding these difficulties is to utilise a reluctance stepper motor which has its rotor within the tube and its stator externally thereof. Since the rotor or a reluctance motor does not carry any windings, it can be safely and easily in talled within the tube. However the magnetic flux between the stator and the rotor must pass through the tube wall in order to provide actuation of the rotor. The tube wall providdes generally circumferentially extending flux leakage paths. Consequently a large number of ampere turns are required in the stator coils in order to obtain an acceptable level of torque from the rotor. This leads to large current and associated losses so that it is usually necessary to provide the stator coils with some form of liquid cooling.

It is an object of the present invention to provide a reluctance device which provides stepwise rotary motion and which has a barrier interposed between the rotor and stator portions thereof, the device having improved resistance to the leakage and dissipation of magnetic flux between the rotor and stator portions.

According to the present invention, a reluctance device which provides stepwise rotary motion comprises two or more units each unit comprising a rotor having to aligned, annular, axially spaced apart arrays of teeth, a tubular member within which said rotor is coaxially mounted for rotation relative thereto, said tubular member having two aligned axially spaced apart arrays of teeth mounted on the internal surface thereof to confront said teeth on said rotor in radially spaced apart relationship, and a coaxially mounted annular stator positioned externally of said tubular member in abutting relationship therewith, said stator enclosing a coil which is so positioned that when electrically energised, it creates a plurality of cyclic magnetic flux paths which each extend radially between said rotor and stator *via* said confronting teeth and said tubular member and axially along both said rotor and the portion of said stator located radially outwardly of said coil the portion of said tubular member intermediate said axially spaced apart teeth thereon being adapted to resist the axial passage of said flux paths therethrough.

Said tubular member is preferably provided with an annular non-magnetic insert intermediate said axially spaced apart arrays of teeth in order to resist the axial passage of said flux paths therethrough.

Said reluctance device may comprise a plurality of said units, the stator of adjacent units abutting to define annular passages for the passage of a cooling fluid therethrough.

Said cooling fluid may be a liquid.

Said reluctance device may comprise three of said units, the teeth on each on each of the rotors of said units being displaced by one third of a tooth pitch with respect to the teeth on the remaining units, said teeth on the internal surface of said tubular member being correspondingly displaced.

Said teeth on the internal surface of said tubular member are preferably integral therewith.

Said stator portion radially outwardly of the coil of each unit is preferably in the form of a continuous annulus.

Said coil of each unit may be constituted by a wound conductive tape.

Said tubular member may comprise a portion of a nuclear reactor which is adapted to contain a reactor control rod, said rotor constituting a portion of the drive mechanism for the control rod contained in operation within said tubular member.

The invention will now be described, by way of example, with reference to the accompanying drawings in which

Figure 1 is a sectional view on line A-A of Figure 2 of one unit of a reluctance device in accordance with the present invention.

Figure 2 is a partially sectional view on line B-B of Figure 1 of the reluctance device shown in Figure 1.

Figure 3 is a sectional side view of three units of part of a reluctance device in accordance with the present invention.

With reference to Figure 1 one unit of a reluctance device generally indicated at 10 comprises a rotor 11 which is coaxially mounted (by means not shown) for rotation within a tubular member 12. The rotor 11 is provided with two aligned axially spaced apart annular arrays of radially extending teeth 13 and 14. The tubular member 12 is also provided with two aligned axially spaced apart annular arrays of radially extending teeth 15 and 16 on its radially inner surface 17. The arrays of teeth 15 and 16 on the tubular member 12 are respectively positioned so as to confront the arrays of teeth 13 and 14 on the rotor 11 in radially spaced apart relationship. Although the arrays of teeth 15 and 16 on the tubular member 12 are shown as being integral therewith, it will be appreciated that this is not essential and they may in fact merely abut the tubular member 12.

The tubular member 12 has a stator 18 coaxially mounted externally thereof, which abuts the external surface 19 of the tubular member 12, and surrounds the toothed regions of the tubular member 12 and rotor 11. It consists of two axially spaced apart ring members 19 and 20 which have a coil 21 located

The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

between them and which are linked at their radially outer surfaces by a continuous annular yolk 22. The coil 21 is thus enclosed within the stator 18. It will be appreciated however that the yok 22 need not be continuous and may in fact be constituted by a plurality of discreet members.

If the coil 21 is electrically energised, it creates a number of cyclic magnetic flux paths, two of which are shown as interrupted lines 23 in Fig. 1. Each cyclic magnetic flux path extends radially between the rotor 11 and stator 18 *via* the confronting teeth 13 and 16 and the tubular member 12 and axially along the rotor 11 and the yolk 22. Any tendency for the magnetic flux paths 23 to bypass the rotor 11 and flow axially along the tubular member 12 is resisted by the provision of an annular non-magnetic insert 24 within the tubular member 12. It is envisaged however that other measures could be employed in order to resist such flux leakage. Thus, for instance, the region of the tubular member 12 intermediate the arrays of teeth 15 and 16 could be suitably heat treated. Alternatively the distance between the arrays of teeth 15 and 16 could be so great as to resist such flux leakage.

Thus when the coil 21 is electrically energised and the cyclic magnetic flux paths 23 are created, the teeth 13 and 15 and also the teeth 14 and 16 align themselves, thereby causing the rotor 11 to rotate by up to one tooth pitch depending upon the relative rotational positions of the teeth 13, 15, 14 and 16 prior to the coil 21 being energised. Upon actuation the reluctance device 10 thereby provides a rotational stepwise movement of the rotor 11.

Further stepwise rotational movement of the rotor 11 is provided by using a number of units similar to that shown at 10 in conjunction with each other. Such an arrangement is shown in Figure 3 where three similar units 25, 26 and 27 are arranged in axially abutting relationship with a common yolk 28 and rotor 29. The units 25, 26 and 27 differ only in that the teeth of each unit are displaced by one third of a tooth pitch with respect to the teeth of the remaining units. Thus if the coils 30 of the units 25, 26 and 27 are actuated in turn, they provide continuous stepwise rotational movement of the rotor 29.

The coils 30 may be actuated in turn by the use of mechanical switches of relays. However if it is desired to operate as high efficiency and/or high speed, semi-conductor switches such as thyristors or transistors may be utilised.

The motor which is defined by the three units 25, 26 and 27 may, in certain circumstances, require some degree of cooling. This is readily provided by the passage of a cooling fluid, which may be a liquid, through annular passages 33 which are defined by the stators 34 of the abutting units 25, 26 and 27. It will be appreciated however that the simple construction of the units 25, 26 and 27 makes them amenable to cooling by other means such as forced air cooling.

The simple construction of the units 25, 26 and 27 also makes their manufacture and repair relatively cheap. The coils 30, 31 and 32 are of such a configuration that they may be machine wound and are easily replaceable in the event of their failure. Moreover their configuration is such that they may be constituted by wound conductive tape, such as a foil, instead of wire.

Motors which are made up of a plurality of units 10 in accordance with the present invention are particularly useful for powering the drive mechanisms for nuclear reactor control rods. Thus the tubular member 35 in Fig. 3 could be adapted to contain a reactor control rod and the rotor 29 adapted to drive a screw thread mechanism to raise and lower that control rod. The rotor 29 would be tototally enclosed within the tubular member 35 and would provide control rod drive without the requirement for electrical connections therefrom to the exterior of the tubular member 35.

Although the present invention has been described with reference to a reluctance device which is provided with teeth which are all aligned when they confront each other, it will be appreciated that they may be circumstances in which it is desirable to space the teeth on the rotor and stator so that they are in a vernier relationship with each other. This results in an increase in rotor torque upon coil energisation but a decrease in rotational speed.

CLAIMS

1. A reluctance device which provides stepwise rotary motion comprising two or more units each unit comprising a rotor having two aligned, annular, axially spaced apart arrays of teeth, a tubular member within which said rotor is coaxially mounted for rotation relative thereto, said tubular member having two aligned annular axially spaced apart arrays of teeth mounted on the internal surface thereof to confront said teeth on said rotor in radially spaced apart relationship, and a coaxially mounted annular stator positioned externally of said tubular member in abutting relationship therewith, said stator enclosing a coil which is so positioned that when electrically energised, it creates a plurality of cyclic magnetic flux paths which each extend radially between said rotor and staotr *via* said confronting teeth and said tubular member, and axially along both said rotor and the portion of said stator located radially outwardly of said coil, the portion of said tubular member intermediate said axially spaced apart teeth thereon being adapted to resist the axial passage of said flux paths therethrough.

2. A reluctance device as claimed in claim 1 wherein said tubular member is provided with an annular, non-magnetic insert intermediate said axially spaced apart arrays of teeth in order to resist the axial passage of said flux paths therethrough.

3. A reluctance device as claimed in claim 1 or claim 2 wherein said reluctance device comprises a plurality of said units, the stators of adjacent units abutting to define annular passages for the passage of a cooling fluid therethrough.

4. A reluctance device as claimed in claim 3 wherein said cooling fluid is a liquid.

5. A reluctance device as claimed in any one preceding claim wherein said reluctance device comprises three of said units, the teeth on each of the rotors of said units being displaced by one third of tooth pitch with respect to the teeth on the remaining units, said teeth on the internal surface of said tubular member being correspondingly displaced.

6. A reluctance device as claimed in any one

preceding claim wherein said teeth on the internal surface of said tubular member are integral therewith.

7. A reluctance device as claimed in any one preceding claim wherein the stator portion radially outwardly of the coil of each unit is in the form of a continuous annulus.

8. A reluctance device as claimed in any one preceding claim wherein the coil of each unit is constituted by a wound conductive tape.

9. A reluctance device as claimed in claim 5 wherein said tubular member comprises a portion of a nuclear reactor which is adapted to contain a reactor control rod, said rotor constituting a portion of the drive mechanism for the control rod contained in operation within said tubular member.

10. A reluctance device substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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