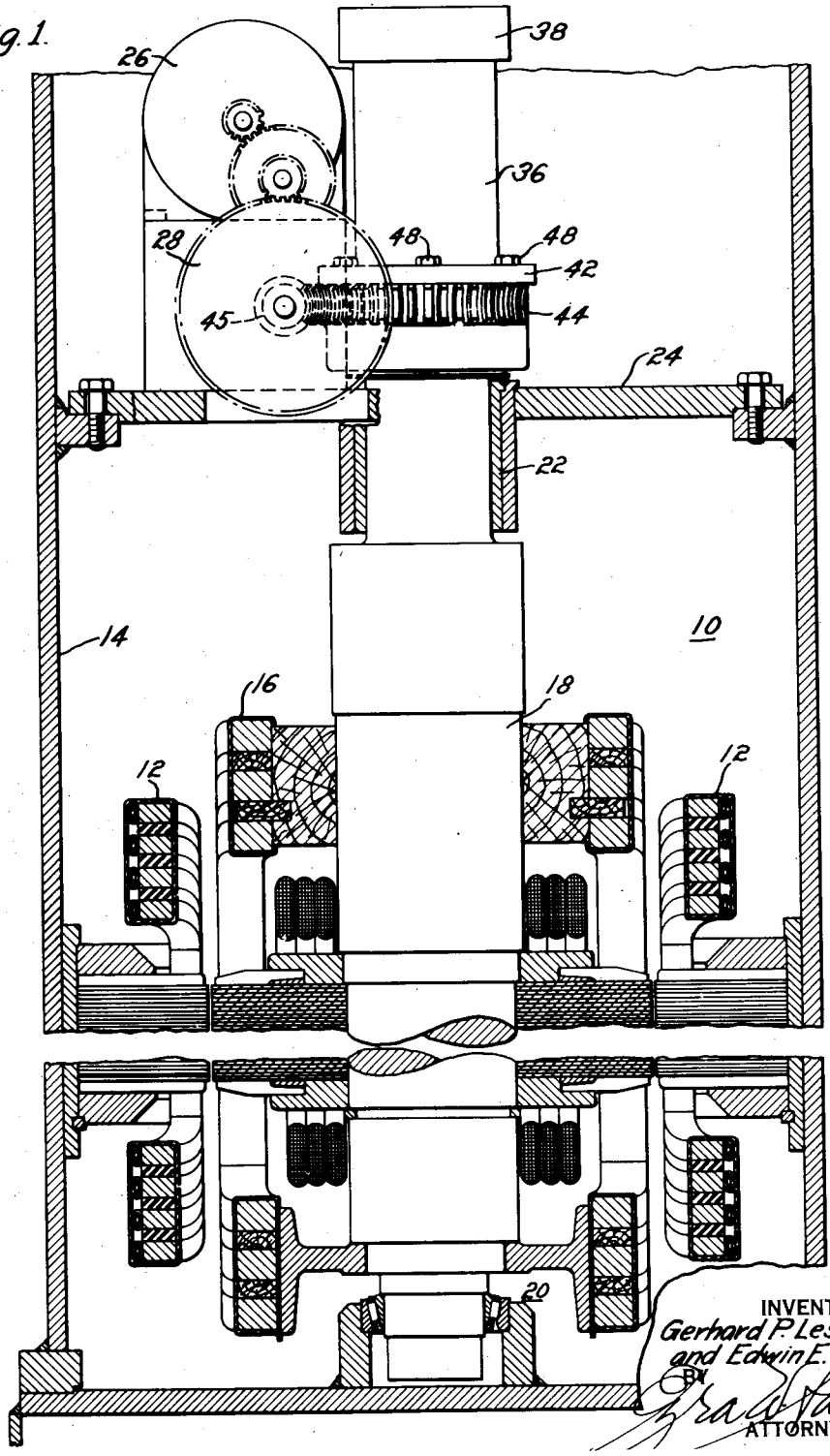
May 20, 1941. G. P. LESSMANN ET AL 2,242,360

INDUCTION REGULATOR

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Fig. 1.



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Fig. 2.

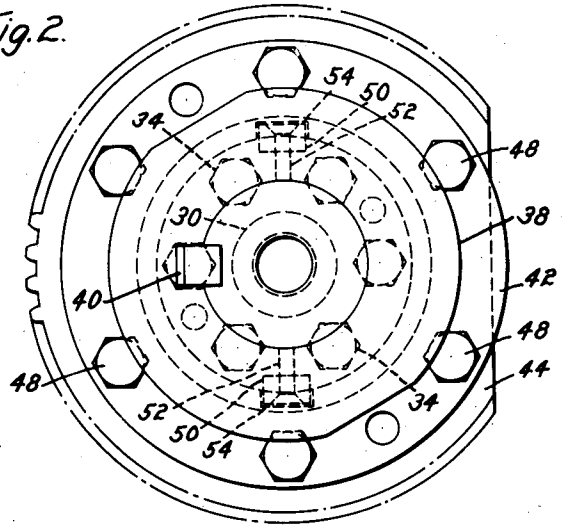
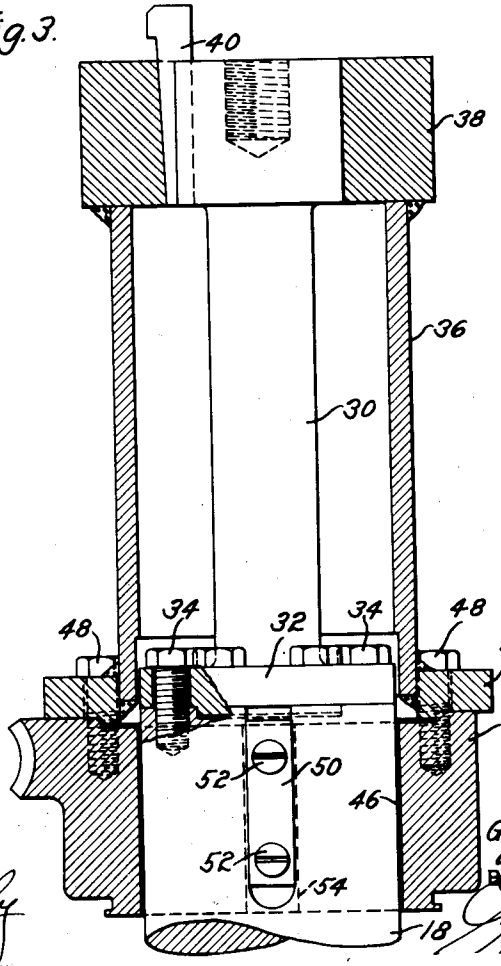


Fig. 3.



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INDUCTION REGULATOR

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5 Claims. (Cl. 171—119)

The invention relates generally to induction regulators and more particularly to the actuating mechanism for the regulator rotor.

When a regulator includes a gear train it has been found that under certain operating conditions that chattering results. This affects the life of the regulator.

Different attempts have been made to prevent the transmission of the torque impulses to the gear train of the drive, but these have not been altogether satisfactory in that they have the disadvantage of greatly increased cost of apparatus, increased size of apparatus, or the drive fails under short circuit torque conditions.

An object of this invention is to provide an induction regulator having a flexible drive which will prevent chattering of the gears of the drive.

A more specific object of this invention is to provide a flexible drive between the main shaft of an induction regulator and the gears utilized for driving the rotor whereby the amplitude of torsional oscillation transmitted to the gear train under the torque impulses caused by the frequency will be less than the deflection of the shaft imposed on the regulator by the average torque, thereby preventing chattering of the drive.

A further object of this invention is to provide a flexible drive between the main shaft of an induction regulator and the gear utilized in the drive of the regulator for preventing chattering of the gear, together with means for directly connecting the shaft of the induction regulator to the gear under abnormal operating conditions of the regulator to prevent straining of the flexible drive beyond its elastic limit.

Other objects of this invention will become apparent from the following description, when taken in conjunction with the accompanying drawings, in which:

Figure 1 is a vertical sectional view of an induction regulator embodying the teachings of this invention;

Fig. 2 is a top plan view of a part of the flexible coupling of this invention; and

Fig. 3 is an elevational view partly in section of the flexible coupling utilized in the drive of this invention.

Referring to Fig. 1 of the drawings, this invention is illustrated as applied to an induction regulator 10. The regulator comprises a stator winding 12 suitably mounted within a tank 14 and a cooperating rotor winding 16 carried by a vertical shaft 18. The vertical shaft 18 is supported in operative position within the tank 14 by means of supporting bearings 20 and 22, the latter being carried by a horizontal strap or flange 24 disposed within and across the tank 14 near the end of the shaft 18. The stator winding 12 and rotor winding 16 are usually immersed in oil (not shown) in the tank 14 which completely encloses the regulator windings.

A motor 26 is carried within the tank 14 below the cover (not shown) by the strap or flange 24 and is disposed to drive a train of gears 28 for actuating the vertical shaft 18 in a predetermined manner.

Since the vertical shaft 18 is quite stiff, it has an extremely high natural frequency. Under torque conditions such as will exist where a current having a predetermined frequency is supplied to the stator winding 12, the vertical shaft 18 carrying the rotor winding 16 is under a forced vibration having a frequency equal to the frequency of the current. Under operating conditions, the frequency producing the torque distortion force is fixed at some predetermined frequency, such as 25 cycles.

As is well known, where torsional forces are applied to a shaft, the amplitude of the torsional oscillation is dependent upon the relation of the natural frequency of the shaft and the steady or forced frequency of the force which produces the torsional force. Where the forced frequency is maintained constant, such as where the current supplied to the stator winding 12 has a frequency of 25 cycles, the amplitude of oscillation in the shaft may be decreased by decreasing the natural frequency of the shaft. Such a decrease in the natural frequency of the shaft may be secured by decreasing the stiffness of the shaft.

In induction regulators of the type illustrated in Fig. 1, it is not practical to decrease the stiffness of the main vertical shaft 18 because of the strength requirements for supporting the rotor winding 16 and withstanding the stresses encountered in operation. Ordinarily, the shaft 18 is of such size that under the influence of the average torque developed by the current supplied to the winding 12, the shaft will be distorted a predetermined amount. Thus if the vertical shaft 18 were directly connected to the train of gears 28, since the shaft 18 has a very high natural frequency and the amplitude of oscillation is greater than the distortion of the shaft due to the average torque, the vibrations or oscillations delivered through the shaft 18 to the train of gears would be so great as to cause chattering of the teeth of the gears in the drive.

In order to provide a flexible drive between the

shaft 18 and the gear train 28, an auxiliary shaft 30 having a flange member 32 at its lower end, as illustrated in Fig. 3, is secured in aligned relation at the end of shaft 18 as by means of the screws 34. The auxiliary shaft 30 has a much smaller diameter than the shaft 18 and has a natural frequency much less than the natural frequency of the shaft 18.

Due to the space considerations in the tank 14, it is necessary to provide for connecting the auxiliary shaft 30 to the drive at a point adjacent the end of the main shaft 18. In the embodiment illustrated, a sleeve 36, which is preferably metallic, is utilized for connecting the auxiliary shaft 30 to the drive. The sleeve 36 is provided with an annular flange member 38 at one end and is secured thereto as by means of a shield. The sleeve 36 is secured to the outer end of auxiliary shaft 30 by means of the tapered key 40 and is disposed in operative position concentrically about and extending back upon the shaft 30.

The sleeve member 36 has an outwardly extending flange member 42 secured in any suitable manner as by means of a weld at its end opposite the annular member 38. This flange member 42 functions to carry the worm 44 which cooperates with the worm gear 45 of the drive, the worm being disposed concentrically about the main vertical shaft 18 having a slight clearance 46 therewith as illustrated in Fig. 3. As illustrated in Fig. 1, the worm 44 is disposed to be directly engaged by the worm gear 45 of the gear train 28, whereby the motor 26 can drive the main vertical shaft 18 to position the rotor winding 16 with respect to the stator winding 12 as desired. The worm 44 is secured to the flange member 42 in any suitable manner such as by means of the screws 48.

Under normal operating conditions the natural frequency of the auxiliary shaft 30 is less than the line frequency imposed on the stator and the amplitude of torsional oscillation developed in the shaft 30 and transmitted to the end of the sleeve carrying the worm is less than the deflection of the shaft under the average torque developed under normal conditions of operation by imposing the line frequency on the stator. Under these conditions chattering between the worm 44 and its cooperating worm gear 45 of the gear train 28 is not encountered.

If the space conditions are so limited that it is impossible to utilize an elongated auxiliary shaft 30 having the desired natural frequency for producing torsional oscillations having an amplitude of less value than the distortion of the shaft 18 under the torsional force applied, then the metallic sleeve 36 can be so designed as to be utilized for cooperating with a shorter auxiliary shaft 30 for giving the desired natural frequency. In practice, however, it is found that the auxiliary shaft 30 will usually have the necessary flexibility so that for practical purposes the design of the metallic sleeve 36 can be such as to function primarily for the purpose of connecting the shaft 30 with the worm 44 of the drive. Whether the metallic sleeve 36 is utilized for the express purpose of cooperating with the shaft 30 for giving the desired natural frequency or whether it is employed merely as a connector for connecting the shaft with the drive, it is found that the shaft 30 and the sleeve 36 cooperate for producing and transmitting an amplitude of oscillation to the worm 44 which is less than the deflection of the shaft under the average torque developed under normal conditions of operation by imposing the line frequency on the stator.

Under short circuit conditions such as are sometimes encountered in service, a short circuit torque is developed and applied to the shaft 18 producing a stress therein. If this deflection or stress under the short circuit torques is applied to the auxiliary shaft 30 and sleeve member 36, the flexible drive may be destroyed, since the applied torques may be above the yield point of the combined auxiliary shaft 30 and sleeve member 36.

In order to prevent the application of the short circuit torques and, consequently, the high stresses to the flexible drive comprising the auxiliary shaft 30 and sleeve member 36, a direct drive is provided for keying the shaft 18 directly to the worm 44 when the deflection of the shaft under the short circuit torques reaches a predetermined amount.

This direct drive, as illustrated in Figs. 2 and 3, is formed of one or more keys 50 secured to the main vertical shaft 18 as by means of the screws 52 fitted into a cooperating slot 54 disposed on the inside wall member of the worm 44. The slot 54 of the worm member 44 and the key 50 carried by the vertical shaft 18 are so designed that sufficient clearance is obtained between the key and the edge of the slot as to permit the normal distortion of the shaft 18 under normal operating conditions without engaging the wall of the slot in worm 44. However, the clearance between the key 50 and the side walls of the slot 54 is also designed to limit the deflection which can be applied to the auxiliary shaft 30 and the sleeve member 36 to a point below the yield point of the metallic members forming the flexible coupling, so that the deflection of the shaft 18 under short circuit torque is transmitted directly to the worm 44 without causing undue stress in the flexible coupling. Thus the auxiliary shaft 30 and the sleeve member 36 are free from static twist, such as would be encountered under short circuit torque conditions.

Since the flexible coupling utilized in the drive of this invention has a natural frequency less than the forced frequency imposed on the windings of the regulator and the amplitude of torsional oscillation is, therefore, limited to an amount less than the deflection of the shaft under average torque conditions, it is quite evident that chattering of the gears of the drive is prevented under normal operating conditions of the regulator. Further, by utilizing the drive of this invention, the entire operating mechanism of the regulator can be completely encased, providing a non-chattering regulator while at the same time preventing straining under short circuit conditions of the chatter restraining apparatus.

Although this invention has been described with reference to a particular embodiment thereof, it is, of course, not to be limited thereto except insofar as is necessitated by the prior art and the scope of the appended claims.

We claim as our invention:

1. In an induction regulator provided with a stator disposed to have a line frequency imposed thereon and a rotor disposed in cooperative relation with the stator, in combination, a shaft disposed to carry the rotor, the shaft being deflected a predetermined amount under the average torque developed when the line frequency is

imposed on the stator, a drive for operating the rotor, the drive including a worm and gear, and an auxiliary shaft connected to the rotor shaft and to the worm of the drive, the auxiliary shaft having a natural frequency less than the line frequency imposed on the stator whereby the amplitude of torsional oscillation developed in and transmitted through the auxiliary shaft is less than the deflection of the shaft under the average torque developed by imposing the line frequency on the stator and shattering between the worm and gear of the drive is prevented.

2. In an induction regulator provided with a stator disposed to have a line frequency imposed thereon and a rotor disposed in cooperative relation with the stator, in combinaiton, a shaft disposed to carry the rotor, the shaft being deflected a predetermined amount under the average torque developed when the line frequency is imposed on the stator, a drive for operating the rotor, the drive including a worm and gear, an auxiliary shaft connected to the rotor shaft, a sleeve connected to the outer end of the auxiliary shaft and extending back upon it, the sleeve being connected to the worm of the drive, the auxiliary shaft having a natural frequency less than the line frequency imposed on the stator whereby the amplitude of torsional oscillation developed in the shaft and transmitted through the sleeve to the worm is less than the deflection of the shaft under the average torque developed by imposing the line frequency on the stator and chattering between the worm and gear of the drive is prevented.

3. In an induction regulator provided with a stator disposed to have a line frequency imposed thereon and a rotor disposed in cooperative relation with the stator, in combination, a shaft disposed to carry the rotor, the shaft being deflected a predetermined amount under the average torque developed when the line frequency is imposed on the stator, a motor for operating the rotor, a train of gears including a worm and worm gear between the motor and the shaft, an auxiliary shaft connected to the rotor shaft, a sleeve connected at one end to the outer end of the auxiliary shaft and extending back upon it, the sleeve carrying the worm at its other end for connecting with the worm gear of the train of gears, the auxiliary shaft and sleeve cooperating and having a natural frequency less than the line frequency whereby the amplitude of torsional oscillation developed in and transmitted to the end of the sleeve carrying the worm is less than the deflection of the shaft under the average torque developed by imposing the line frequency on the stator.

4. In an induction regulator provided with a stator disposed to have a line frequency imposed thereon and a rotor disposed in cooperative relation with the stator, in combination, a shaft disposed to carry the rotor, the shaft being deflected a predetermined amount under the average torque developed when the line frequency is imposed on the stator, a drive including a worm and worm gear for operating the rotor, an auxiliary shaft connected to the rotor shaft and to the worm of the drive, the auxiliary shaft having a natural frequency less than the line frequency imposed on the stator whereby the amplitude of torsional oscillation developed in and transmitted through the auxiliary shaft is less than the deflection of the shaft under the average torque developed by imposing the line frequency on the stator and chattering between the worm and worm gear of the drive is prevented, and means carried by the rotor shaft for directly engaging the worm under abnormal operating conditions for directly transmitting torsional force to the worm to prevent straining of the auxiliary shaft beyond its elastic limit.

5. In an induction regulator provided with a stator disposed to have a line frequency imposed thereon and a rotor disposed in cooperative relation with the stator, in combination, a shaft disposed to carry the rotor, the shaft being deflected a predetermined amount under the average torque developed when the line frequency is imposed on the stator, a motor for operating the rotor, a train of gears including a worm and a worm gear between the motor and the shaft, an auxiliary shaft connected to the rotor shaft, a sleeve connected at one end to the outer end of the auxiliary shaft and extending back upon it, the sleeve carrying the worm at its other end for connecting with the worm gear of the train of gears, the auxiliary shaft and sleeve cooperating and having a natural frequency less than the line frequency whereby the amplitude of torsional oscillation developed in and transmitted to the end of the sleeve carrying the worm is less than the deflection of the shaft under the average torque developed under normal conditions of operation by imposing the line frequency on the stator, and means carried by the rotor shaft for directly engaging the worm under abnormal operating conditions to prevent straining of the auxiliary shaft and sleeve beyond their elastic limit.

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