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G. ZANARINI

MECHANICAL ENERGY TRANSDUCTOR BASED ON GYROSCOPIC REACTION

Filed May 10, 1941

Serial No. 392,983

3 Sheets-Sheet 1

Fig. 1

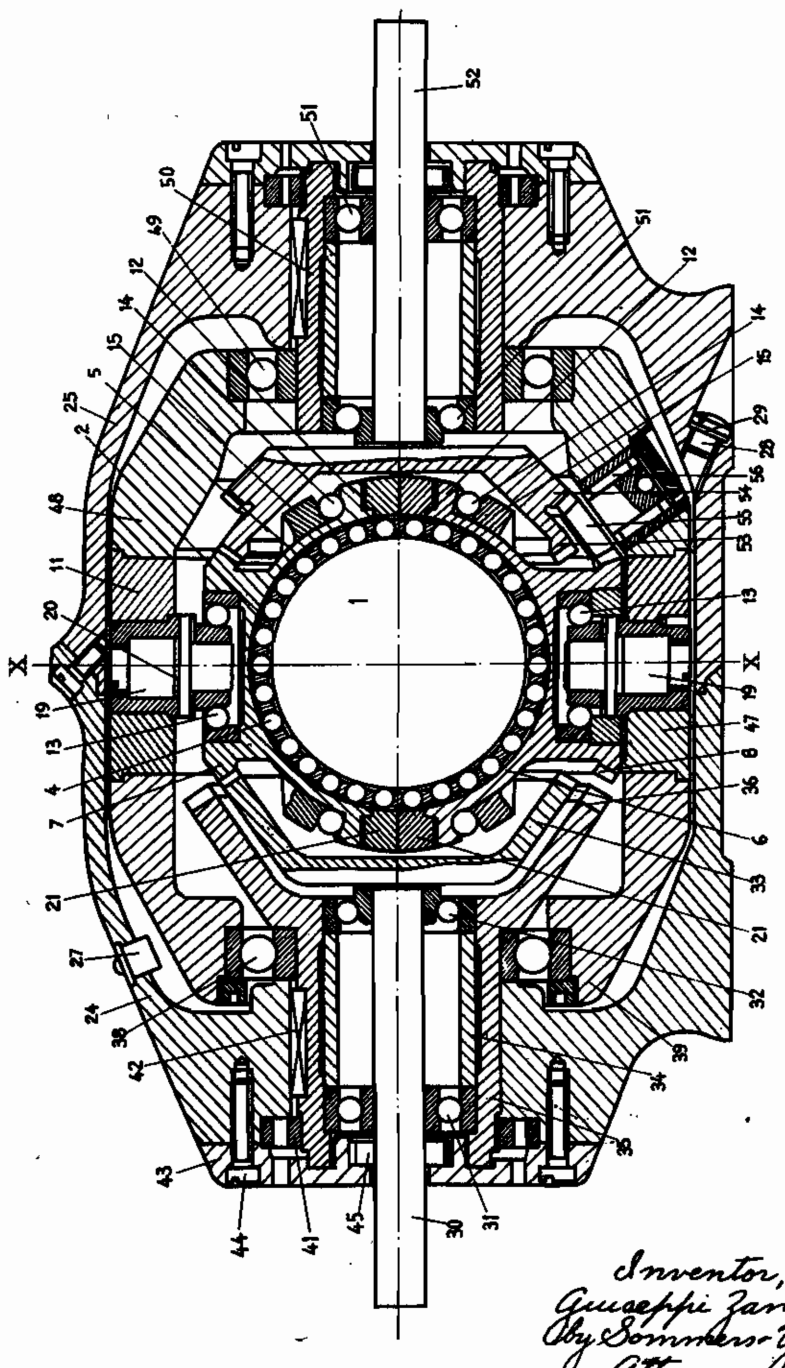

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Fig. 2

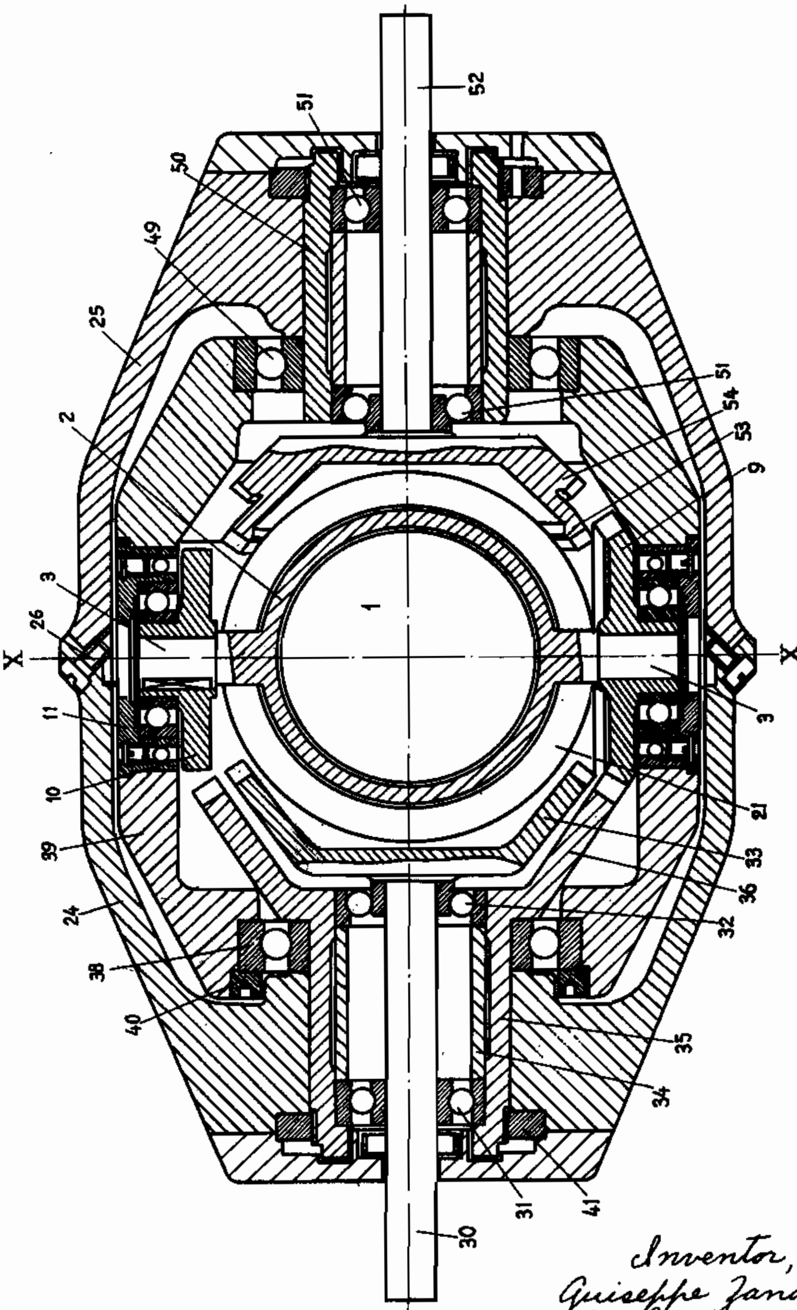

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Fig. 3

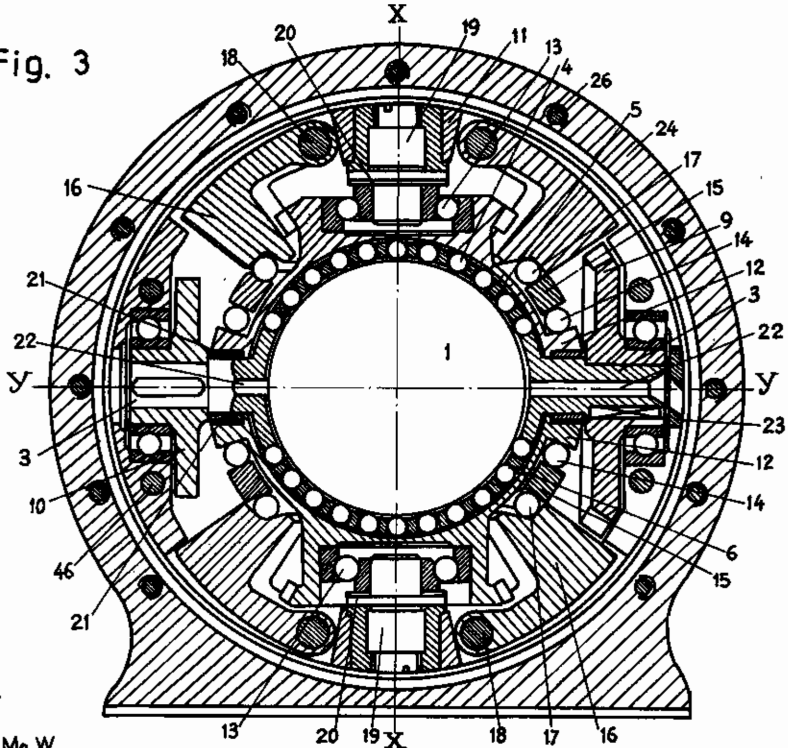


Fig. 4

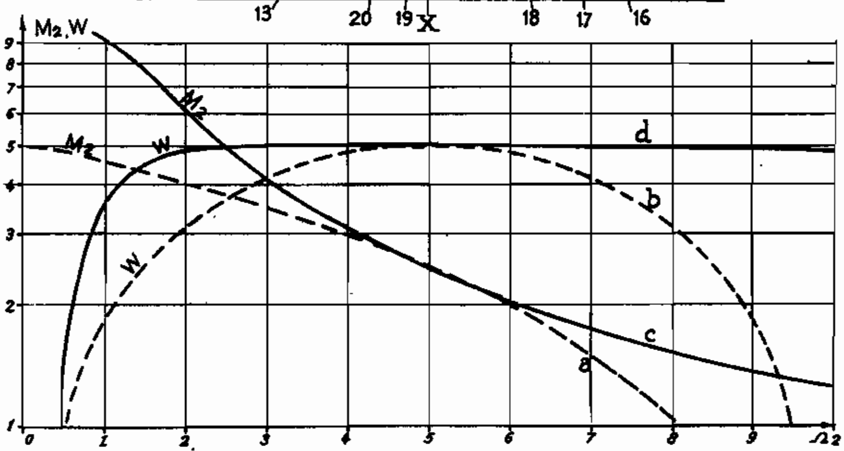
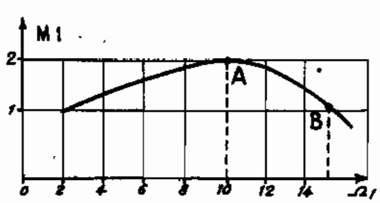


Fig. 5



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ALIEN PROPERTY CUSTODIAN

MECHANICAL ENERGY TRANSDUCTOR BASED ON GYROSCOPIC REACTION

Giuseppe Zanarini, Turin, Italy; vested in the Alien Property Custodian

Application filed May 10, 1941

This invention relates to a mechanical transducting device in which the energy is in the form of rotatory motion. The device has a ratio of angular speed automatically and continuously variable in function of the resistance torque acting on the driven shaft.

According to this invention, the resistance torque on the driven shaft is balanced by a twisting moment of equal value originated by the gyroscopic reaction of a heavy sphere to which a motion of precessional character is imparted by the driving shaft by means of a suitable kinematic connection.

The functional characteristic of the transductor, according to the invention, lies in the transformation of mechanical energy which, from the driving shaft, is transmitted to the driven shaft; such transformation is attained by means of a dynamic action depending on the mass of the heavy sphere, and is a continuous function of the resistance torque which acts upon the driven shaft of the transductor.

The construction characteristic of the device, according to the invention, lies in the kinematic connection by means of which it is possible to apply to the heavy sphere a precessional motion whereby mass dynamic actions are attained which cause the transformation of the mechanical energy which is transmitted from the driving shaft to the driven shaft in said transductor.

The annexed drawing shows by way of example an embodiment of this invention.

Fig. 1 is an axial section of the device according to the invention

Fig. 2 is a section on line Y—Y of fig. 3

Fig. 3 is a cross section,

Figures 4 and 5 are diagrams of the transmission characteristics of the device.

The heavy sphere 1, which must fulfil the condition that the moment of inertia with respect to a whatever diameter be a constant, is surrounded by a spherical cage 2 provided with two pivots 3 and a plurality of holes in which the small balls 4 of equal diameter are placed. The unit constituted by the sphere 1, cage 2 and small balls 4 is then enclosed in two calottes 5 and 6 having a spherical inner surface and a radius of curvature exactly equal to the sum of the radius of the sphere 1 and diameter of the small balls 4. The X—X axis of rotation of said calottes, is normal to the Y—Y axis of rotation of the cage and the plane of the two axes contains the center of the sphere 1; furthermore, the axis of rotation of the calottes 5 and 6 is normal to the axis of the precessional motion, which also contains the center of the sphere 1.

The two calottes 5 and 6 are provided with two toothed wheels 7 and 8 respectively, keyed thereon, by means of which it is possible to apply to both calottes an equal and concordant rotatory motion around the X—X axis.

The cage 2 is provided with a toothed wheel 9 fast with one of the two oppositely arranged pivots 3. Upon the other pivot is rigidly keyed the wheel 10, in order to balance, with respect to the center of gravity of the system, the mass of the toothed wheel 9.

The system just described is mounted upon four ball bearings or other suitable support disposed in a orthogonal cross arrangement on the outside ring 11, acting as the support of the system itself.

The two calottes 5 and 6 are provided with flanges 12 which act as a frame for a sliding thrust bearing. The system is formed by said flanges 12, balls 14 rolling in a groove formed in the flanges themselves, ground rings 15 pressing upon the balls 14 and balance weight 16 acting on the ring 15 through the rolling elements 17.

If the ring 11 is supposed to rotate about the precession axis, which as already mentioned is the axis through the center of the sphere 1 normal to the X—X and Y—Y axes, the centrifugal force tends to raise the balance weights 16 which, tending to rotate around the pivots 18 cause a thrust upon the rolling elements 17 and then, through said thrust bearing sliding system, upon the calottes 5 and 6 which tend to approach pressing on the small balls 4.

Furthermore, the calottes 5 and 9 are partially pressed by the thrusts attained by means of the adjustable pivots 19, pressing upon the thrust bearings 13 on which said calottes are set through the bearing plates 20 which provide a constant pressure.

The inside surface of each of the two calottes 5 and 6 extend with respect to the center, through an angle smaller than 180° in order to let the pivots 3 out from the annular space existing between the two opposite calottes. In order to eliminate the discontinuity resulting by this arrangement on the whole inner surface of the two calottes, (this discontinuity may cause the small balls 4 to come out through the cage holes when they pass through said discontinuity, owing to the centrifugal force), said annular space receives an antifriction ring 21 against which the facing sides of the two calottes slide in contact.

The inner surface of the ring 21 (which may be formed in two sections for an easier mounting) is spherically ground with the same radius of curvature of the surface of the two calottes. Furthermore, said ring, the width of which is slightly larger than the diameter of the cage pivots 3, is provided with two calibrated holes through which said pivots protrude.

Fig. 1 shows a section of the ring through said pivots. Thus the small balls 4, dragged by the cage 2 can roll from one calotte to the other without meeting any discontinuity on the spherical surface.

The above described assembly forms the kinematism characterizing the construction of the transductor according to the invention.

Now, assuming to apply to both calottes 5 and 6 and to the cage 2, by means of the toothed wheels, two rotatory motions having angular speeds ω_c and ω_g respectively, if the pressure acting on the calottes is sufficient to supply the necessary adherence to the system, the sphere 1 will receive, by rolling and without sliding action, a rotatory motion of speed ω_f about an axis through the center of the sphere contained in the X—Y plane and with a slope, with respect to the X—X axis, equal to the α angle defined by:

$$\text{tang } \alpha = \frac{2\omega_g}{\omega_c}$$

Furthermore we have:

$$\omega_f = \frac{D+2d}{D}\sqrt{\omega_c^2+4\omega_g^2}$$

in which:

D=diameter of the sphere 1.
d=diameter of the small balls 4.

If, finally, we cause the outside bearing ring 11 to rotate with an angular speed Ω about the X—X axis containing the center of the sphere 1 and normal to the X—Y plane, the sphere 1 is subject to a precessional motion characterized by a relative speed ω_f about the axis f and by a speed Ω about the precession axis.

As a consequence of this motion, in the sphere 1 a gyroscopic couple M will originate, due to the additional acceleration, the representative vector of which results normal to the vector ω_f and is contained in the X—Y plane.

The result is that said couple M, through the kinematic connections above described, reacts upon the calottes and upon the cage, giving rise to two orthogonal components Mc and Mg respectively on the X—X and Y—Y axes.

Of said vectors Mc and Mg, one has a driving direction and the other the reverse direction with respect to the coaxial vectors ω_c and ω_g (or viceversa according to the direction of the various speeds) and therefore the former forms a couple which tends to accelerate the motion and the latter tends to brake it.

Said property, therefore, represents the substantial characteristic of the transductor according to the invention.

Said couples Mc and Mg, according to the invention, may be utilized for a continuous and automatic transformation of the energy by means of proper kinematic connections to both the driving and driven shaft of the transductor in the system just described.

The form of the transductor transformation characteristic depends upon said connections; however, in all cases, the characteristic maintains a continuous and automatic character depending upon the resistance torque on the driven shaft.

As an example of practical construction, a transductor according to the invention, will now be described, in which the transformation characteristic approaches the case of constant power when the resistance torque on the driven shaft varies.

As far as lubrication is concerned, the pivots 3 of the cage 2 are provided with two oil-ducts 22 in order to lead the oil to the inner sphere 1.

Said oil-ducts are properly deviated outside (when passing through the bearing disc 23) in order to cause the lubricant to follow the ducts by force of inertia.

The outside box which acts as a support and as a lubricant reservoir, is made in two parts 24 and 25 fastened together by means of the screws 26. Said box is provided with a plugged hole 27 for introducing the lubricant and an additional plugged hole 28 provided with a gasket 29 for allowing change of lubricant.

The driving shaft 30 is mounted on two ball bearings 31 and 32 and forms a unit with a toothed bevel wheel 33 which engages the toothed bevel wheel 7 fastened to the calotte 5.

The two ball bearings 31 and 32 are separated by a ring 34 and fixed inside the sleeve 35 which forms a single assembly with an additional toothed wheel 36 which engages the toothed wheel 9 of the cage 2. To the sleeve 35 is fastened a ball bearing 38 which supports the ring 38, this being attached to the ball bearing by means of the threaded elastic bearing plate 40. The sleeve 35 is axially adjustable by means of the threaded bearing plate 41; the key 42 prevents it from rotating with respect to the box section 24.

The cover 43, fastened to the box section 24 by means of the screws 44, is provided with a cylindrical chamber in which the stuffing box 45 is placed in order to avoid oil leakage.

The ring 39 is fastened by means of the screws 46 to the ring 47, ring 11 and ring 48 which is supported by a ball bearing 49 and mounted on the sleeve 50.

Inside the sleeve 50 two ball bearings 51 are fixed which support the driven shaft 52 which forms a single assembly with toothed bevel wheel 53 and 54 respectively.

The toothed bevel wheel 53, engages the toothed bevel wheel 7, fastened to the calotte 5 while the toothed bevel wheel 54 engages the bevel pinion 55, mounted in the thrust needle bearing 56 fixed on the ring 48. The pinion 55 engages the toothed bevel wheel 8 which is a part of the calotte 6.

The system for adjusting and closing the transductor on the side of the driven shaft is similar to the one described for the driving shaft. The transmission rations of the toothed wheel must be such as to cause the calottes 5 and 6 to rotate at the same angular speed and direction.

The substantial part of the transductor, previously described, is supported by the rings 11 and 47.

Supposing now that the driving shaft of the transductor rotates at an angular speed of Ω_1 and the driven shaft rotates with an angular speed of Ω_2.

If R designates the ratio between the number of teeth of the toothed wheel 33 fixed to the driving shaft **30** and the number of teeth of the toothed wheel **7** fixed to the calotte **5**, then:

$$\Omega=\frac{1}{2}(\Omega_1-\Omega_2)=$$

angular speed of the rings **11** and **47** about the Z—Z axis=angular speed of the axis of precession of the sphere **1**.

$$\omega_g=\frac{1}{2}R(\Omega_1+\Omega_2)=$$

angular speed of the toothed wheel **9** fixed to the cage **2** about the axis Y—Y of the cage itself.

$$\omega_c=\frac{1}{2}R(\Omega_1+\Omega_2)=$$

angular speed of the two calottes **5** and **6** about their own axis.

$$\omega^*=R_a\sqrt{\frac{5}{4}(\Omega_1^2+\Omega_2^2)-\frac{3}{2}\Omega_1-\Omega_2}=$$

relative angular speed of the sphere **1** about the axis of the precession.

$$M_g=\frac{1}{2}Ra^2J(\Omega_1^2-\Omega_2^2)=$$

braking couple originated by the gyroscopic couple of the sphere on the cage axis Y—Y.

$$M_c=\frac{1}{2}Ra^2J(\Omega_1-\Omega_2)^2=$$

driving couple originated by the gyroscopic couple on the calotte axis Y—Y.

$$M_1=\frac{1}{2}Ja^2R^2(\Omega_1-\Omega_2)\Omega_2=$$

couple of the driving shaft.

$$M_2=\frac{1}{2}Ja^2R^2(\Omega_1-\Omega_2)\Omega_1=$$

couple acting on the driven shaft=resistive couple.

$$W=\frac{1}{2}Ja^2R^2(\Omega_1-\Omega_2)\Omega_1\Omega_2=$$

power transmitted by the transductor, in which J=moment of inertia of the reacting sphere **1** with respect to one diameter

$$a=\frac{D+2d}{D}$$

in which: D=diameter of the sphere **1**
d=diameter of the small balls **4**.

When $\Omega_2=0$ the max couple on the driven shaft is obtained:

$$M_2\ \max=\frac{1}{2}Ja^2R^2\Omega^2$$

together with zero power drawn by the driving shaft as:

$$\Omega_2=0 \qquad M_1=0$$

Therefore the transmission characteristic results from the type represented in Fig. 4. The curve *a* shows on an arbitrary scale, the couple on the driven shaft in function of the angular speed of the latter for a given angular speed of the driving shaft.

The curve *b* shows an arbitrary scale, the power transmitted in function of the angular speed of the driving shaft.

The curves *c* and *d* refer to a condition where the angular speed of the driving shaft varies with the load for instance, coupling with internal combustion engines, operating in the portion AB of the characteristic diagram of the driving couple given in Fig. 5.

In such instance, the transmission characteristic approaches even more the case of constant power and therefore is particularly suitable for propulsion purposes.

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