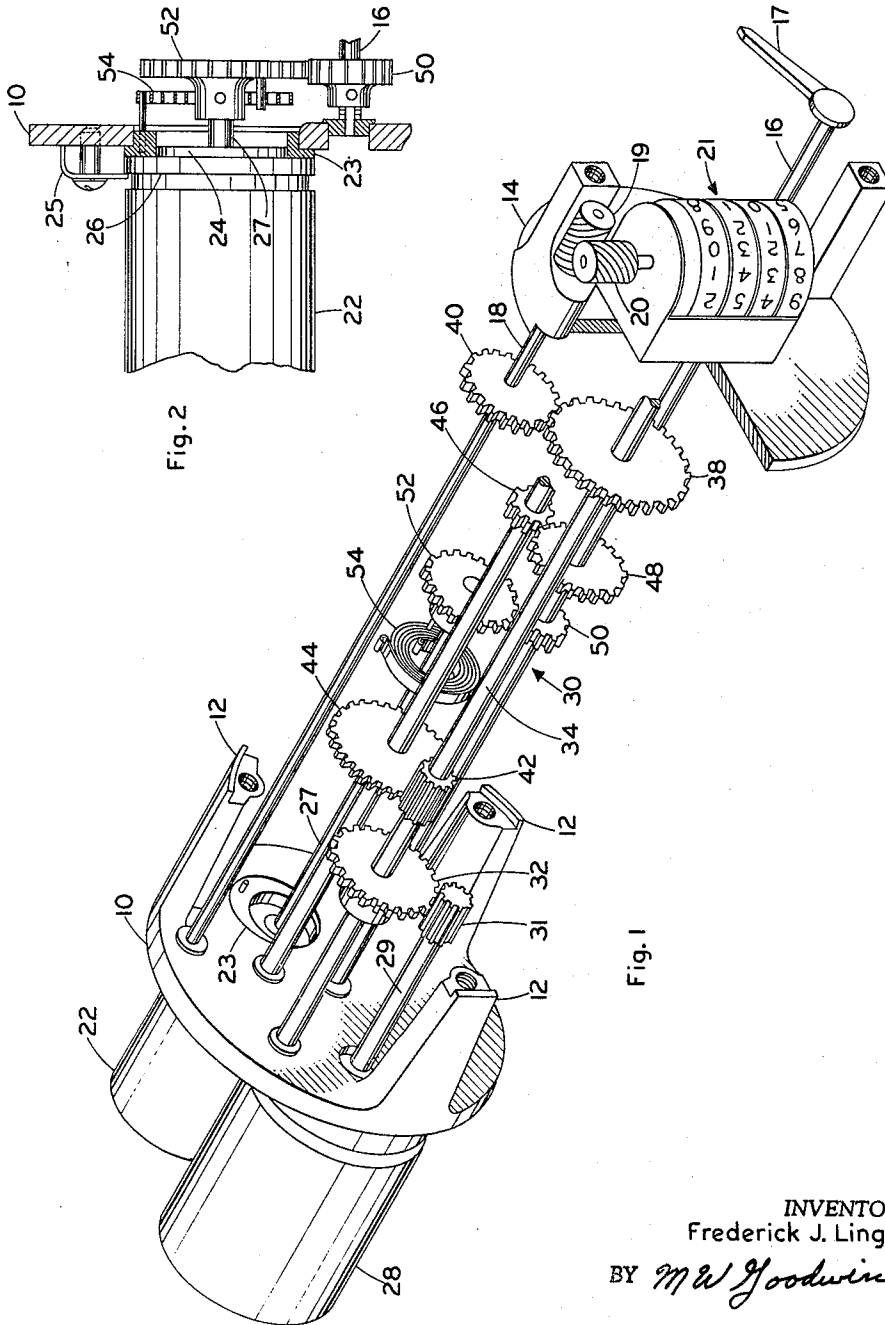


Nov. 15, 1960

F. J. LINGEL
ELECTRICAL BACKLASH PREVENTION FOR GEAR
TRAIN OF SERVO ACTUATED DEVICE
Filed Nov. 17, 1958

2,959,975



INVENTOR.
Frederick J. Lingel
BY *M W Goodwin*

His Attorney

1

2,959,975

ELECTRICAL BACKLASH PREVENTION FOR GEAR TRAIN OF SERVO ACTUATED DEVICE

Frederick J. Lingel, Lynnfield Center, Mass., assignor to General Electric Company, a corporation of New York

Filed Nov. 17, 1958, Ser. No. 774,226

4 Claims. (Cl. 74—409)

This invention relates to servo actuated devices and more particularly to a servo actuated device having a gear train or the like connected at one end to a drive motor which is actuated by servo control means of the null type.

The use of servo actuated motors for driving a gear train or the like as well as the connection of the gear train to the servo control means controlling the motor for providing nulling of the servo signal is well known. In such a system, any backlash in the gear train will effect the accuracy of the output of the train and may also result in a reduced service life of the gear train due to vibration and chatter of the gears. It is therefore desirable to at least substantially eliminate the backlash in such a gear train. One known means of accomplishing this end is to provide extremely close manufacturing tolerances on the gears in the train so as to reduce the backlash to a minimum. However, the cost of manufacturing such precision gears is very high and is prohibitive in many cases. Another known solution of the backlash problem is to provide a spring biasing the first drive gear in the train so as to urge all of the gears in the train in one direction of movement thereof and take out the backlash throughout the train. This arrangement of course requires a relatively high torque on the biased gear where a substantial number of gears are provided in the train and thus results in a relatively large error torque being introduced into the train which may adversely affect the accuracy of the system. In addition, the power output of the motor driving the train must be proportionally increased to compensate for the torque added by such a backlash compensating spring.

Accordingly, it is the object of this invention to provide novel and improved anti-backlash means for a gear train or the like connected at one end to a driving motor actuated by null type control means also connected to the gear train, which will eliminate the necessity for a relatively large biasing force on any portion of the gear train that might adversely affect the accuracy of movement of the servo system, and which will permit the use of low manufacturing tolerance gears in the gear train thus effecting a reduction in cost of manufacture while improving the accuracy and sensitivity of the system.

Other objects and advantages of the invention will be in part described in detail and in part obvious from the following description.

In one aspect of the invention there is provided a servo actuated device including servo control means for providing an electrical signal and which includes a movable member for effecting nulling of the signal in response to movement of the movable member. Electrically actuated motive means are connected to the control means for actuation in response to said signal, and a gear train is drivingly connected at one end to the motive means and at its other end to at least one output shaft. The gear train is also connected to the movable member of the control means by means of a driven gear rigidly connected to the movable member for movement

2

therewith and with the driven gear meshed with a driving gear thus completing a known configuration of a servo actuated device of the null type. In accordance with the invention, biasing means are provided tending to urge the movable member of the control means in one direction of movement thereof so as to tend to provide a signal to the motive means to effect actuation thereof to drive the gear train in a direction tending to move the control member in a restraining direction opposite said one direction of movement thereof. The force of the biasing means is selected to be sufficient to move the driven gear and the movable member relative to the driving gear as permitted by backlash between said driving and driven gears but to be insufficient to cause any significant driving movement of the driving gear by the spring biased driven gear directly. In other words the spring is far from sufficient to remove the backlash in the entire gear train directly and mechanically. However, the signal to the motive means will as a result of the spring urged relative movement of the movable member effect actuation of the motive means so as to cause the motive means to wind up the gear train sufficiently to take out the backlash throughout the entirety thereof. The backlash correction means therefore introduces no significant error torque into the system while at the same time it effects removal of the backlash in the train so as to improve the accuracy and sensitivity of the train and increase the service life thereof.

A more detailed understanding of the invention may be had by reference to the accompanying drawing in which

Figure 1 is an exploded perspective view of a portion of an exemplary servo actuated device embodying the invention; and

Figure 2 is an enlarged fragmentary side view, partly in section, of a portion of the structure of Figure 1.

With reference to the drawing, there is shown a portion of an exemplary servo actuated device adapted to provide a remote indication of a quantity under measurement and which comprises a base or frame 10 having up-standing legs or supports 12 angularly spaced about the periphery of the frame for supporting a mounting plate 14 on which is journaled a pointer shaft 16 carrying a pointer 17 which is associatable with an indicia bearing dial, not shown, for indicating a quantity. Also journaled on the plate 14 is a shaft 18 carrying a helical gear 19 for movement therewith which is engaged with a second helical gear 20 for driving a counter 21 which is also carried by the plate 14. The counter, as will be apparent, is not limited to any particular construction.

Mounted on the plate 10 is control means 22 which in the specific embodiment shown is a synchro control transformer having a stator, not shown, adapted to be connected to a remote transmitter, not shown, for providing an electrical signal to the control transformer in a known manner. The control transformer is mounted on the plate 10 by means of annular mounting ring 23 rotatably received in an aperture in the plate 10 and having an eccentric aperture receiving a cylindrical hub portion 24 on the transformer. A clamp 25 on the plate 10 is engageable with an annular shoulder or ridge 26 on the periphery of the transformer 22 to rigidly hold the transformer and ring 23 in rotatably adjusted position relative to the plate 10. The synchro control transformer 22 also includes a rotor, not shown, which is drivingly connected to a shaft 27 for positioning the rotor relative to the stator of the control transformer. The rotor of the control transformer 22 is adapted to be electrically connected, such as through an amplifier, to a control phase of an electric drive motor 28 mounted on the frame 10 to provide for actuation of the motor in response to a signal from the control transformer.

The motor has a drive shaft 29 drivingly connected to the end of a gear train 30 to provide motive means for the train. A pinion 31 is mounted on the shaft 29 for movement therewith and is drivingly engageable with a gear 32 mounted on a shaft 34 journaled at its opposite ends on the frame 10 and plate 14. The shaft 34 through gears 38 and 40 drives the counter shaft 18 and through gears 42, 44, 46, 48 drives the pointer shaft 16. A driving gear 50 rigidly mounted for movement with the pointer shaft 16 is engageable with a driven gear 52 mounted for movement with the control transformer shaft 27 to provide for positioning of the rotor of the control transformer to a null position in response to a signal from the control transformer to the motor 28. The adjusting ring 23 provides a means for adjusting the axis of the shaft 27 and thus gear 52 relative to the axis of the gear 50 for adjusting the meshing and hence backlash of the gears 50 and 52.

In accordance with the invention, biasing means in the form of a helical spring 54 is arranged about the hub of the gear 52 on the control transformer shaft with the inner end of the spring being fixed to a pin on the gear 52 and with the outer end of the spring being fixed to a pin on the adjustable mounting ring 23 mounting the control transformer on the frame 10. The spring 54 is preferably pre-loaded by means of adjustment of the mounting ring 23 when the pointer 17 and counter 21 are in a zero position so as to provide a predetermined torque upon the transformer shaft 27. The spring force of the spring 54 is selected to provide that the spring will have sufficient strength to move the synchro rotor shaft 27 when the shaft is not loaded by the motor 28 as will occur when there is play between the teeth of the gears 50 and 52 and the teeth of the gears are not tightly engaged in driving relationship. In other words the spring should be strong enough so as to be able to rotate the shaft 27 and gear 52 directly and take up at least a portion of the backlash between the gears 50 and 52. The force of the spring is selected however to be insufficient to cause directly any significant movement of the shaft 27 when the gears 50 and 52 are tightly engaged in the direction corresponding to the direction that the spring 54 urges the shaft 27 thus precluding any purely mechanical movement of the gear train 30 by the spring 54. The spring 54 thus need only be strong enough to move the driven gear 52 in a direction tending to take up the backlash between the gears 50 and 52 and should not be strong enough to take up the backlash throughout the entire gear train.

Movement of the gear 52 and thus the shaft 27 by the spring 54, in the manner described above, will however effect a signal from the control transformer to the motor 28 to cause movement of the drive shaft 29 so as to drive the gear train in a direction opposite that of the movement of the shaft 27 by the spring 54 with the result that the teeth of the gears of the train will be firmly engaged so as to eliminate vibration and chatter in the gear train either during movement of the train or when the device is in a steady-state condition. As will be obvious, equally good results may be obtained whether the control transformer rotor is biased in a downscale or an upscale direction. It will of course be noted that if the control transformer rotor shaft 27 is biased in a direction tending to effect downscale movement of the motor, a signal from the transmitter effecting an upscale movement of the motor will result in instantaneous relative movement between the gears of the gear train as the play in the train is taken up in the opposite direction, which relative movement will also occur instantaneously when upscale movement ceases and the spring 54 effects actuation of the drive motor in the opposite direction to re-engage the gear teeth in the opposite direction. However, this very limited amount of instantaneous relative movement in the gear train is a very small part of the relative move-

ment which would occur between gears in the train if the anti-backlash means of this invention were not provided and does not affect the instrument performance or accuracy.

While the invention has been described in terms of the specific embodiment shown in the drawing, it will of course be apparent to those skilled in the art that it may find application in other null type servo systems associated with a drive gear train or the like where it is desired to provide means for taking up the play between the driving and driven elements of the train. In other words, it is contemplated that the control means for the motor could be in the form of other known devices for providing a signal wherein the device includes a movable member for nulling the signal provided by the device including but not limited to potentiometers, slide wires, and differential transformers. Further, the motive means could obviously be other than the motor shown. Additionally the biasing means for the movable member of the control element is, as will be apparent to those skilled in the art, not limited to a spring such as shown in the preferred embodiment but may take other forms equally well known in the art such as tapered magnets, gravity, a wind-off spring, etc. Also, as will be apparent, the invention is not necessarily limited to application to a gear train composed entirely of gears but also may find application to other drive trains of driving and driven elements where there is play between the driving and driven elements of the train such as might occur in linkages, sprocket and chain drives, etc. Therefore, while the foregoing description has been presented in terms of the specific embodiment disclosed, it is to be understood that the scope of the invention is not limited to this specific embodiment but rather includes all modifications and alternative embodiments which logically fall within the language of the appended claims and the terms of the claims shall include all structures which are logical alternatives and/or equivalents therefor.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a servo actuated device, control means for providing an electrical signal and including a movable member for effecting nulling of said signal in response to movement of said movable member, electrically actuated motive means responsive to said signal, an output shaft, a gear train drivingly connecting said motive means to said output shaft and to said movable member and including a driven gear rigidly connected to said movable member for movement therewith and a driving gear meshed with said driven gear, electrical anti-backlash means for said gear train including adjustable means for adjusting the relative position of the axes of said driving and driven gears, and a spring connected at one end to said driven gear and at its other end to said adjustable means so that the force of said spring may be adjusted in response to movement of said adjustable means, said spring urging said movable member in one direction of movement and directly providing a torque on said driven gear sufficient to provide movement of said movable member and said driven gear relative to the driving gear in one direction of rotation of said driven gear so as to effect actuation of said motive means in a direction tending to move said driving gear in a direction to oppose movement of said driven gear in said one direction by said spring but with said torque being insufficient to provide any significant driving movement of said driving gear by said driven gear.

2. In a servo actuated device, control means for providing an electrical signal and including a movable member for effecting nulling of said signal in response to movement of said movable member, electrically actuated motive means responsive to said signal, an output shaft, a gear train drivingly connecting said motive means to said output shaft and to said movable member including a driven gear rigidly connected to said movable member for

5

movement therewith and a driving gear meshed with said driven gear, adjustably mounted eccentric means supporting one of said driving and driven gears for adjusting the relative position of the axes of said gears, and a coil spring surrounding the axis of said driven gear and urging said movable member in one direction of movement, said spring being connected at one end to said eccentric means to provide adjustment of the force of the spring in response to adjustment of said eccentric means, said spring further directly providing a torque on said driven gear sufficient to provide movement of said movable member and said driven gear relative to the driving gear in one direction of rotation of said driven gear but with said torque being insufficient to provide any significant driving movement of said driving gear by said driven gear.

3. In a servo actuated device, an output shaft, a drive motor, a gear train interconnecting said motor and said shaft, means comprising a control device having a rotor member for controlling said drive motor, gear means comprising a driving gear connected to said output shaft and a driven gear connected to said rotor member for positioning said rotor, anti-backlash means powered by said motor through supplemental adjustment of said control device comprising a spring connected to apply torque to said driven gear to take up backlash in said driving and driven gears and adjusting means permitting adjustment of the axial distance between said driving and driven gears to vary the play between said gears and hence the position of the rotor of said control device relative to said output shaft.

6

4. In a servo actuated device, an output shaft, a drive motor, a gear train interconnecting said motor and said shaft, means comprising a control device having a rotor member for controlling said drive motor, gear means comprising a driving gear connected to said output shaft and a driven gear connected to said rotor member for positioning said rotor, anti-backlash means powered by said motor through supplemental adjustment of said control device comprising a spring connected to apply torque to said driven gear to take up backlash in said driving and driven gears and adjusting means connected to one of said gears and said spring for effecting a simultaneous adjustment of the torque applied to said driven gear by said spring and the play between said driving and driven gears.

References Cited in the file of this patent

UNITED STATES PATENTS

20	2,196,231	Ridgway	Apr. 9, 1940
	2,507,555	Berthiez	May 16, 1950
	2,537,083	Peoples	Jan. 9, 1951
	2,679,167	Nichinson	May 25, 1954
25	2,763,161	Bergson	Sept. 18, 1956
	2,792,869	Halvorsen	May 21, 1957

OTHER REFERENCES

Machine Design: Precision Gearing, February 1955, pages 200-205.