Oct. 23, 1951 C. F. SCHAEFER 2,572,523

TORQUE AMPLIFIER

Filed Jan. 18, 1950 2 SHEETS—SHEET 1

Fig 1

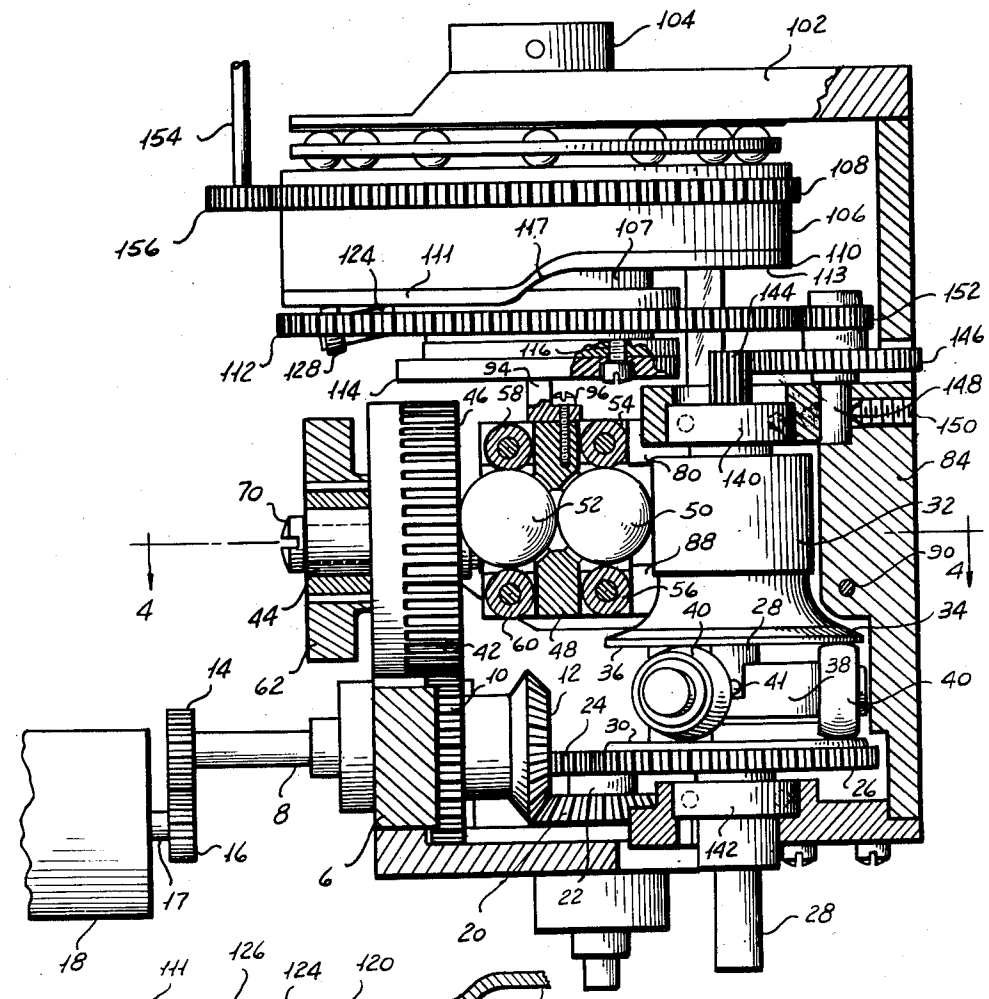


Fig 2

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Fig 3

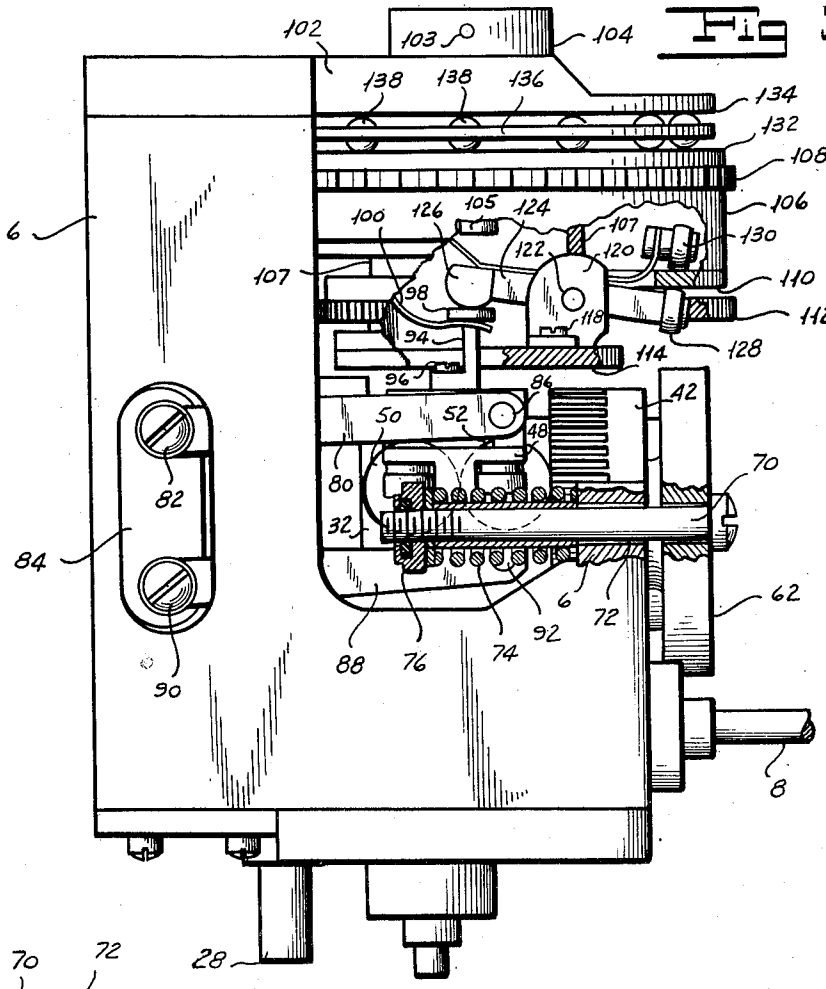
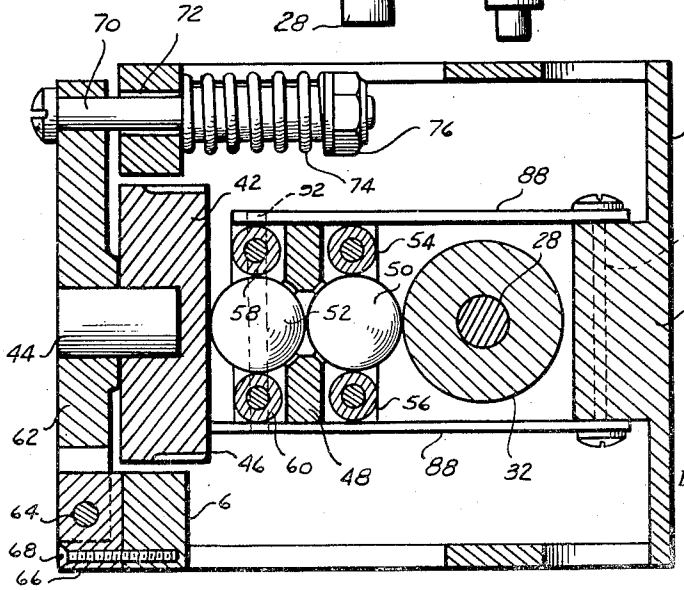


Fig 4



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TORQUE AMPLIFIER

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8 Claims. (Cl. 74—388)

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My invention relates to a torque amplifier and more particularly to a torque amplifier of simple and sturdy construction.

Torque amplifiers are used in many devices where it is desired to move an output part in conformity to the motion of an input part where the force on an input shaft, for example, is small and it is desired to have an increased torque on the output shaft. One example of the application of a torque amplifier is in the case of airplane controls. The torque applied to the controls by the pilot may be kept small while an increased torque may be applied to the control surfaces which are made to follow precisely the movement of the control by the pilot. Then too, in computers, bomb-sights and in many other applications small forces are available for exercising control when large forces are desired for moving parts.

One object of my invention is to provide a torque amplifier having relatively few moving parts which is simple in construction and sure in its operation.

Another object of my invention is to provide a torque amplifier in which overloads are easily disposed of by slippage of parts while not disturbing the phase of operation of my device.

Other and further objects of my invention will appear from the following description.

In the accompanying drawings which form part of the instant specification and which are to be read in conjunction therewith and in which like reference numerals are used to indicate like parts in the various views:

Figure 1 is a front elevation of a torque amplifier containing one embodiment of my invention with parts in section.

Figure 2 is a fragmentary perspective view with parts in section showing a detail.

Figure 3 is a rear elevation of the torque amplifier shown in Figure 4 with the parts broken away.

Figure 4 is a sectional view taken along the line 4—4 of Figure 1.

In general my invention contemplates the provision of an input torque from a constant speed motor of any suitable construction. The motor is adapted to drive one side gear of a friction roller differential and a driving disc. The driving disc drives the other side element of the friction roller differential through a displaceable friction drive the position of which is controlled by a follower coacting with a cam. The output shaft which comprises the differential shaft is geared to drive a member on which the follower is

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mounted. The cam is provided with a step and when the follower is positioned on the step the arrangement is such that the speed of the roller which comprises one side gear of the differential is equal and opposite to the speed of the gear comprising the other side gear of the differential. When this condition exists the shaft is stationary. The cam is rotatably mounted and the input is applied to the cam. The rotation of the cam will displace the follower to cause the differential shaft to rotate in the direction of the displacement and at the same speed. In other words, the parts are so arranged and constructed that the movement of the differential shaft seeks to parallel the movement of the input shaft in direction and in velocity.

Referring now to the drawings, a frame 6 rotatably carries an input shaft 8, to which is secured a gear 10 and a bevel gear 12, both positioned within the frame. Secured to the shaft 8 for rotation therewith I provide a gear 14 meshing with a gear 16 secured to a shaft 17 driven by any suitable prime mover such as a motor 18. The bevel gear 12 meshes with a bevel gear 20 secured to a shaft 22 to which is likewise secured a gear 24 meshing with a gear 26 rotatably mounted upon a shaft 28. One side of the gear 26 is formed with a plane surface 30. Rotatably mounted on shaft 28 for relative rotation with respect thereto I provide a roller 32 having a flange 34 formed with a plane surface 36. A spider 38 having arms 120° apart is secured to the shaft 28 by means of pin 41 so that the spider will rotate with the shaft 28. The arms of the spider 38 are provided with friction rollers 40 rotatably carried by the arms. Rollers 40, as can readily be seen by reference to Figure 1, frictionally engage both the surface 30 of the gear 26 and the surface 36 of the roller 32. If the roller 32 is stationary the rotation of the gear 26 will rotate the shaft 28 by rotating the rollers 40 and carrying them around along with their supporting spider 38. If the gear 26 is stationary and the roller 32 rotated the shaft 28 will likewise rotate depending upon the direction of rotation of the roller. If the roller 32 is rotating in one direction and the gear 26 is rotating in the opposite direction at an equal speed, the shaft 28 will remain stationary. The arrangement, it will be readily observed, is a friction roller differential. The gear 10 meshes with a gear 42 rotatably and slidably carried on a shaft 44. The face 46 of the gear 42 is a plane surface and acts as a driving disc. A friction ball carrier 48 is mounted between roller 32 and the driving

face 46 and carries a pair of friction balls 50 and 52. The balls are mounted in a suitable cage upon rollers 54, 56, 58 and 60, as can readily be seen by reference to Figure 1. The arrangement is such that rotation of the gear 42 and its driving face 46 will rotate the ball 52 which will rotate the ball 50 in the opposite direction and thence drive the roller 32. The displacement of the carrier 48 from the center will govern the speed at which the roller 32 is driven. The shaft 44 upon which the gear 42 is mounted is carried by an arm 62 which is pivoted around pin 64 carried in a hinge member 66 secured to the frame 6 by means of the machine screws 68, as can readily be seen by reference to Figure 4. The other end of the pivoted arm 62 is provided with an opening through which a bolt 70 passes. The bolt 70 passes, too, through an opening 72 formed in the frame 6. A spring 74 is under compression between the frame and a nut 76 rotatably secured to the end of the bolt 70. The construction is such that viewed in Figure 4 the pivoted arm 62 is rotated in a clockwise direction by the spring 74, thus carrying the gear 42 toward the roller 32 and exerting pressure upon the friction balls 52 and 50 clamping them between the face 46 of the gear 42 and the roller 32. The gear teeth of the gear 42 are longer than the teeth of gear 10 allowing relative axial movement between the gear 42 and the gear 10.

The friction ball carrier 48 is carried by two pairs of pivoted arms. An upper pair of arms 80 are pivoted around a shaft 82 carried by a bracket 84 formed integrally with the casing 6. The ball carrier 48 is pivotally connected to the end of the upper arms 80 by a shaft 86. The lower pair of arms 88 are pivoted about a shaft 90 positioned in the bracket 84. To the outer ends of these arms 88, by means of pin 92, I pivot the lower portion of the ball carrier 48. A member 94 is secured to the ball carrier 48 by means of machine screws 96 and is formed with a bearing plate 98. A spring 100 extends underneath the plate 98 and urges the member 94, and hence the carrier, upwardly. A horizontal member 102 secured to the casing 6 carries a member 104 in which I position by means of pin 103 a stub shaft 105. Around this shaft I rotatably mount a member 106 formed with an external gear 108 and a cam plate 110. The upper surface of the member 106 is formed with a race 132. The lower surface of the horizontal member 102 is formed with a race 134. A retainer ring 136 retains balls 138 between the races 132 and 134 and forms a thrust bearing therewith. A cup-shaped member 107 is formed with a bearing (not shown) adjacent its upper end pivoting the cup member about the stub shaft 105. A gear 112 is secured to the cup member 107 for rotation therewith. A base plate 114 is secured to the cup member 107 by means of machine screws 116. The base plate carries a bracket 120 secured thereto by means of machine screws 118. Pivotally supported by the bracket 120 by means of a pin 122 I provide a lever 124. One end of the lever is formed with a bearing member 126 adapted to contact the bearing plate 98. The bearing plate 98 is positioned on the axis of rotation of the gear 112 so that as the gear rotates the bearing member 126 will remain in contact with the bearing plate 98 which is being urged upwardly by means of the spring 100. The other end of the lever 124 carries a pair of rollers 128 and 130 which are positioned on opposite sides of the cam plate 110, as can readily be seen by reference to Figure 3.

Referring now to Figure 1, it will be noted that the cam plate 110 is formed with an area 111 and an upwardly positioned area 113. These areas are joined by an inclined portion or step 117. When the cam follower rollers 130 and 128 are in the position of the cam portion 111 the bearing member 126 carried by the lever 124 will be raised permitting the spring 100 to raise the friction ball carrier 48 upwardly and increasing the effective radius of the drive disc surface 46. When the followers 128 and 130 are in the region 113 of the cam 110 the bearing member 126 will be depressed, forcing the friction drive ball carrier 48 downwardly toward the center of the ball driving disc surface 46.

The shaft 28 of the differential is journaled in bearings 140 and 142. To the upper end of the shaft 28 I secure a pinion 144 secured to the shaft for rotation therewith. The pinion meshes with a gear 146 journaled on a stub shaft 148 held in the casing 6 by a set screw 150. Secured to the gear 146 for rotation therewith is a pinion 152 which meshes with the gear 112. An input shaft 154 rotates a gear 156 which meshes with the gear 108.

It is desired in the torque amplifier that the output shaft 28 rotate in accordance with the rotation of the gear 108 both as to amplitude and direction. The construction and size of the parts are such that when the roller 128 is in the middle of the step 117 of the cam plate 110 the speed of the roller will be equal and opposite to the speed of the gear 26. When this condition exists the shaft 28 is stationary.

In operation let us assume that the motor 18 is driving the gear 16 in a counterclockwise direction viewed from the right. The gear 14, the shaft 8 and hence the gear 10 and bevel gear 12 will be rotating in a clockwise direction. The bevel gear 20 and the gear 24 will be driven to rotate in a counterclockwise direction viewed from above, thus driving the gear 26 in a clockwise direction. The rollers 40 will be rotating in a clockwise direction viewed from the front tending to drive the roller 32 in a counterclockwise direction viewed from above. The rotation of the gear 10 in a clockwise direction will rotate the gear 42 in a counterclockwise direction driving the ball 52 in a counterclockwise direction viewed from above. This will drive the ball 50 in a clockwise direction and the roller 32 in a counterclockwise direction, that is, in a direction opposite to the direction of rotation of the gear 26 and at the same speed. Since the speeds of rotation of the roller 32 and the gear 26 are equal and opposite there will be no rotation of the spider 33 and hence no rotation of the shaft 28 to which this spider is attached. It will be observed that in order that the surface 46 of the gear 42 drive the ball 52 in a counterclockwise direction viewed from above, the ball 52 must be positioned above the center of rotation of the gear 42, that is, the point of tangency on the surface 46 with the ball 52 is traveling toward the observer, as viewed in Figure 1. Let us now rotate the gear 108 in a counterclockwise direction viewed from above to bring the roller 128 to the portion 111 of the cam track 112 as shown in Figure 1. When this occurs the roller 128 will move downwardly and the bearing portion 126 carried by the lever 124 will move upwardly as shown in Figure 2. This will permit the spring 100 to move the carriage 48 upwardly bringing the point of tangency of the

ball at a point which has a greater radius and hence a greater lineal speed thus driving the ball 52 in a counterclockwise direction viewed from above at a higher speed and hence rotating the roller 32 at an increased speed in a counterclockwise direction viewed from above. The rollers 40 of the differential will be carried around to rotate the spider 38 in a counterclockwise direction viewed from above, thus rotating the shaft 28 and its pinion 144 in a counterclockwise direction. This will rotate the gear 146 and the pinion 152 in a clockwise direction and rotate the gear 112 in a counterclockwise direction and bring the roller 128, which rotates with the gear 112 back to the step 117.

Let us now assume that the cam member 106 is turned in a clockwise direction by means of the gear 108 through the pinion 156. This will carry the cam plate 110 so that the portion 113 bears against the roller 128 thus raising the roller and the right-hand arm of the lever 124, as shown in Figures 2 and 3. This will depress the bearing member 126 and force the friction ball carriage 48 downwardly against the action of spring 100 bringing the point of tangency of the ball 52 on the friction surface 46 of the gear 42 nearer the center of rotation of the gear 42. This will reduce the lineal speed of rotation of the ball 52 and hence reduce the speed of rotation of the roller 32. The gear 26, however, is still being rotated at a constant speed. The friction rollers 40 of the differential will thus be carried around to the left and will carry with them the spider 38 rotating it in a clockwise direction viewed from above. This will drive the shaft 28 and its attached pinion 144 in a clockwise direction, thus driving the gear 146 and the pinion 152 in a counterclockwise direction. The pinion 152, hence, will drive the gear 112 in a clockwise direction carrying the roller 128 back to the step.

The assumptions made above are extremes. In actual practice, the instant, for example, that the gear 108 rotates in a clockwise direction the roller 32 will immediately be driven to rotate at a faster speed and the shaft 28 will rotate in the same direction as the rotation of the gear 112 with a very small time lag. The speed of rotation, furthermore, of the output shaft 28 will be equal to the speed of rotation of the gear 108. The shaft 154 is driven from a controlling element through an idler gear (not shown) so that the motion of the controlling element and the motion of the output shaft will be in phase at all times. The amplitude rotation of the input will be the amplitude of rotation of the output times a scale factor which depends upon the ratio of the gearing between the input and the output.

It will be observed that due to the use of friction drives both in the differential and for the roller, if a load is momentarily placed upon the output shaft which is too great for the capacity of my torque amplifier, the friction elements will merely slip, and when the load can again be carried the parts will move back into phase, provided of course, that the slippage does not take place for more than 180° of rotation.

It will be seen that I have accomplished the objects of my invention. I have provided a torque amplifier having relatively few moving parts, which is simple in construction and sure in its operation, and in which overloads are easily accommodated for by slippage of parts without disturbing the overall phase of the operation of my device. While it is true that if the slippage occurs the parts will be momentarily out of phase, the slippage is automatically retrieved and the parts placed back into phase relationship. Loads between fairly large limits can be easily accommodated by adjusting the pressure of the spring 74 by means of the nut 76.

It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and is within the scope of my claims. It is further obvious that various changes may be made in details within the scope of my claims without departing from the spirit of my invention. It is, therefore, to be understood that my invention is not to be limited to the specific details shown and described.

Having thus described my invention, what I claim is:

1. A torque amplifier including in combination an input means, a differential output shaft adapted to rotate in phase with the input means with increased torque, a prime mover, a differential having a pair of side members mounted for rotation upon said differential shaft, a mounting means secured to said differential shaft for rotation therewith and positioned between said side members, a rotatable member carried by said mounting means and rotatably contacting both said side members, means for driving one of said side members from the prime mover, a roller secured to the other of said side members for rotation therewith, a disk driven from said prime mover, a variable friction drive positioned between said roller and said disk whereby to drive the other of said side members from said prime mover, means responsive to the movement of the input means for adjusting the variable friction drive whereby to vary the speed of rotation of said roller, and means driven by the differential shaft for controlling the adjusting means.

2. A torque amplifier as in claim 1 in which said means for adjusting said variable friction drive comprises a cam moveable in phase with said input means.

3. A torque amplifier as in claim 1 in which said means driven by the differential shaft for controlling the adjustable means comprises a cam follower.

4. A torque amplifier as in claim 1 in which said side members of the differential comprise friction plates and the rotatable member comprises a friction roller.

5. A torque amplifier as in claim 1 in which said variable friction drive comprises a housing positioned between said disk and said roller and a pair of friction balls rotatably positioned in said housing contacting each other and said friction disk and said roller.

6. A torque amplifier as in claim 1 in which said variable friction drive comprises a housing, means for mounting said housing for movement between the disk and the roller, and a pair of friction balls rotatably carried in said housing contacting each other and the roller and the disk.

7. A torque amplifier as in claim 1 including in combination means for biasing said disk into contact with said variable friction drive.

8. A torque amplifier as in claim 1 in which said means for adjusting the variable friction drive comprises a cam carried by said input means formed with a pair of separated parallel surfaces joined by a step, said means driven by the differential shaft for controlling the adjusting means comprises a rotatable member and a cam follower carried by said rotatable member, the construction being such that when the cam fol-

lower is in position upon said step that the roller will be driven by the variable friction drive at a speed equal to the speed of the other side member of the differential but in the opposite direction whereby said mounting means secured to the differential shaft will be stationary.

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The following references are of record in the file of this patent:

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