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None

(58) Field of search
F2D

(54) Variable-ratio transmission

(57) A chain or belt drive has one or more spiral chainwheels or pulleys. The driving chainwheel 5 is made to oscillate back and forth, perhaps by an eccentric cam. The driven chainwheel 3 also oscillates and drives the output shaft 1 through a one-way clutch 2. The cam driving the driving chainwheel may be shaped in such a way that a constant output speed is produced during the course of each forward stroke despite the continuously changing radius. Slack in the chain is taken up by a chain tensioner, or the spirals are shaped so that no slack occurs. The gearing ratio is changed by changing the relative positions of the output shaft and of the arc through which the driving chainwheel oscillates. The complete transmission generally consists of two or more of these drives, all mounted on the same output shaft and each taking the load in turn.

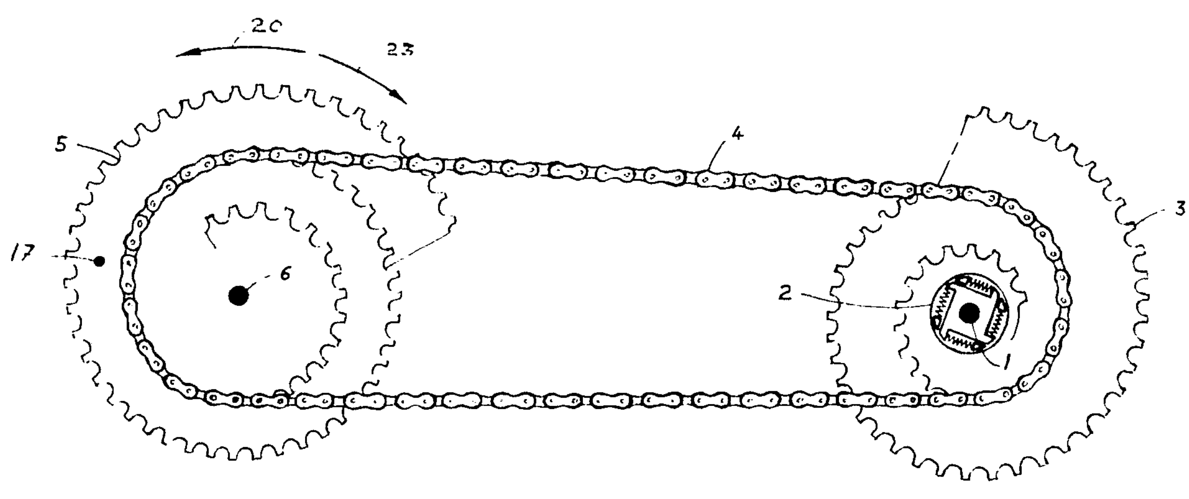

FIGURE 1

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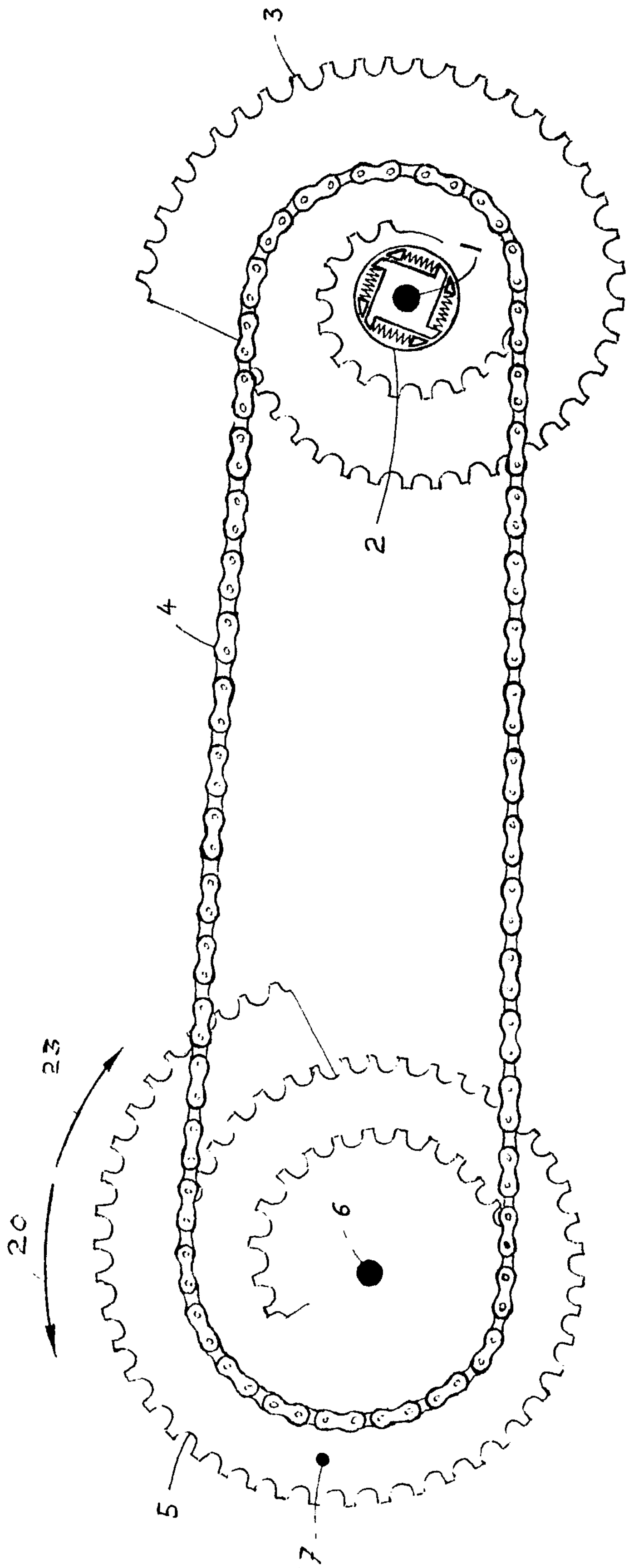


FIGURE 1

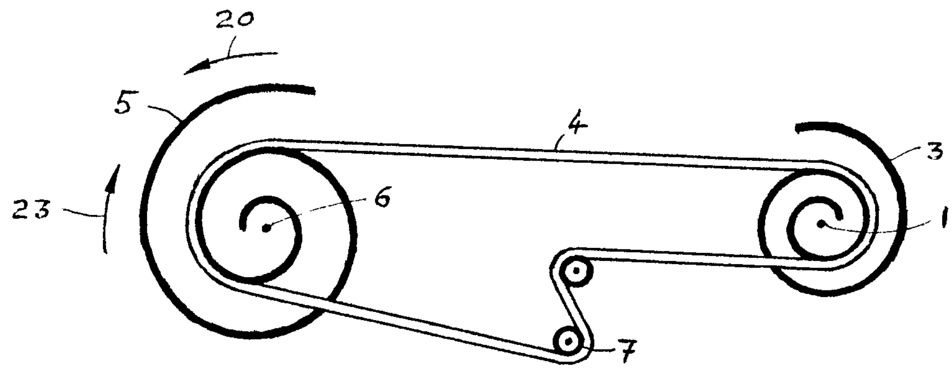
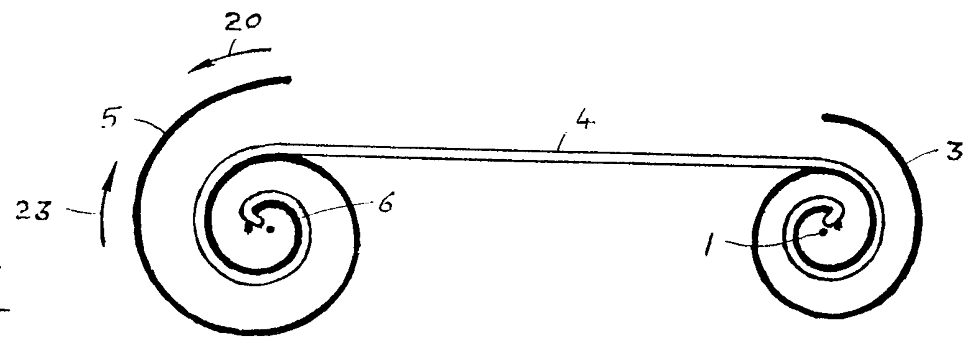


FIGURE 2



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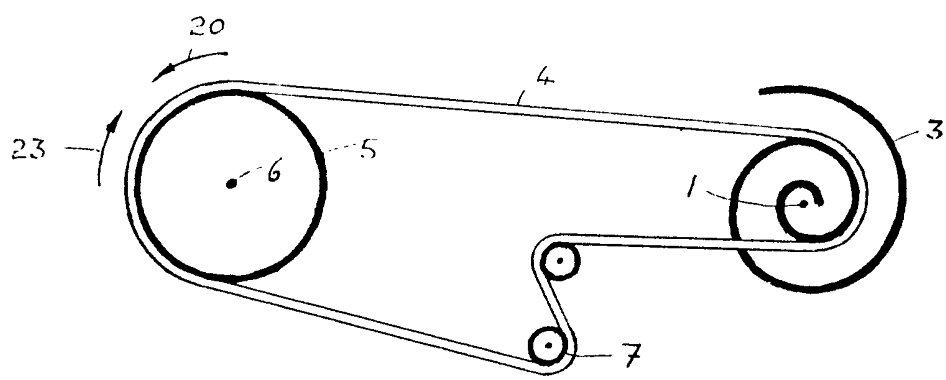


FIGURE 4

FIGURE 5

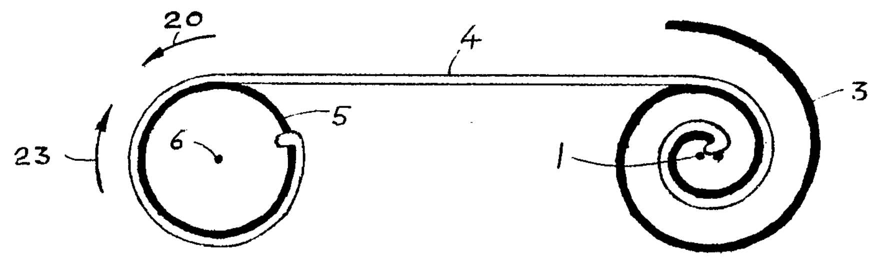


FIGURE 6

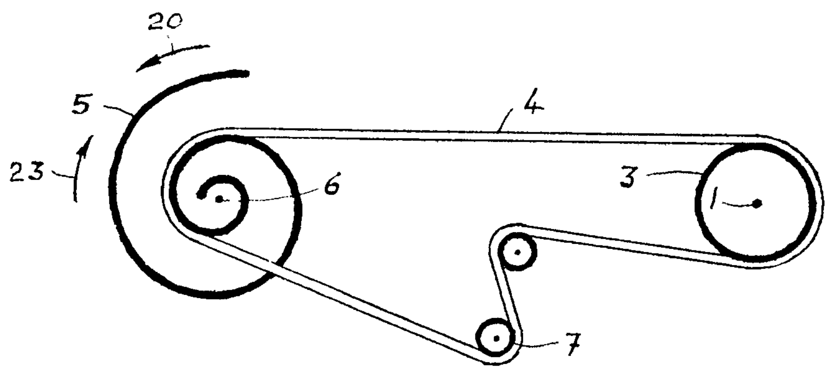


FIGURE 7

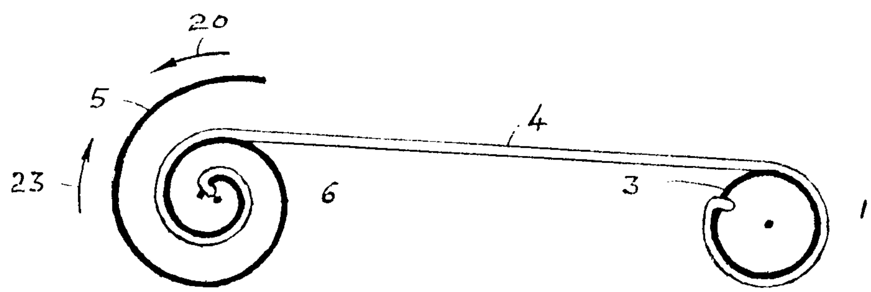
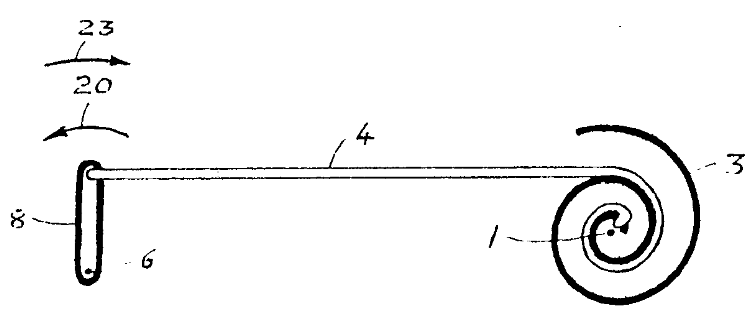


FIGURE 8



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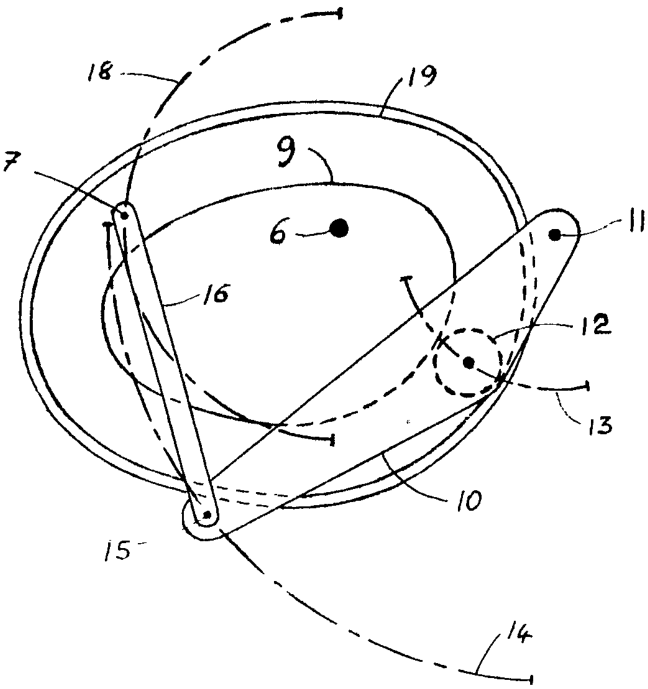

FIGURE 9

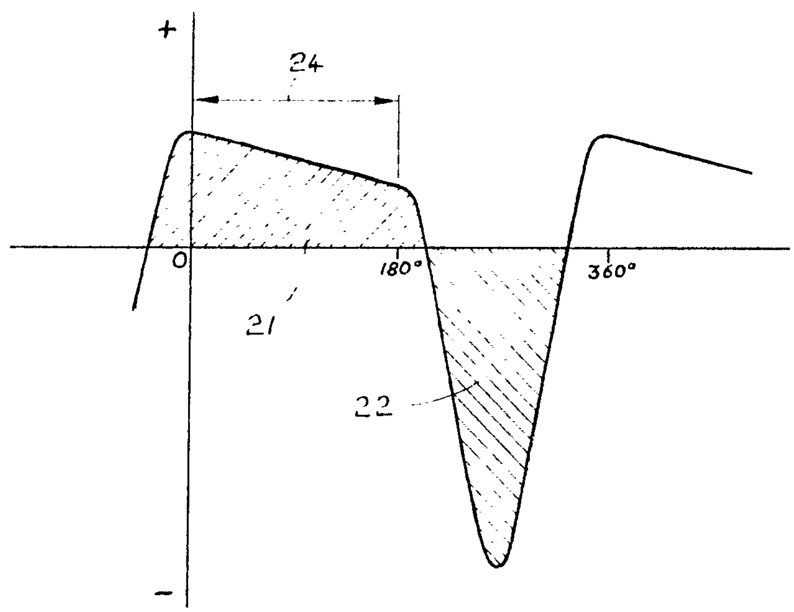

FIGURE 10

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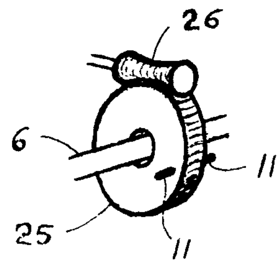


FIGURE 11

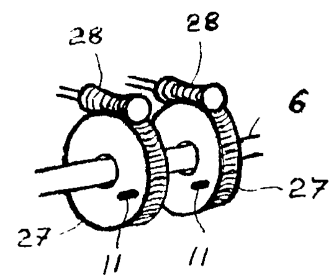


FIGURE 12

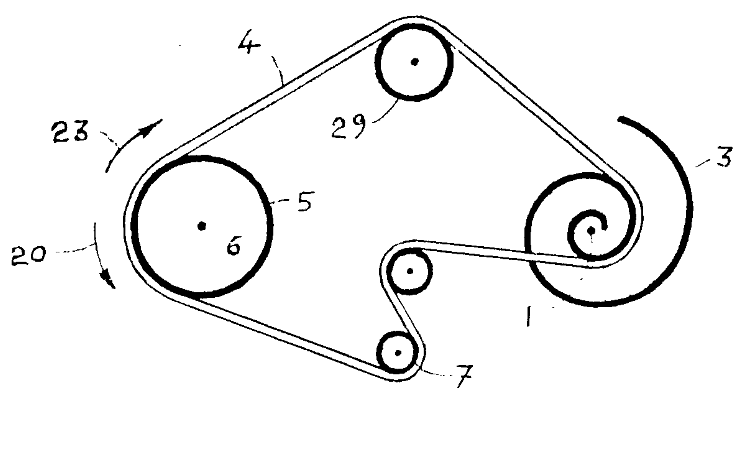


FIGURE 13

Figure 14

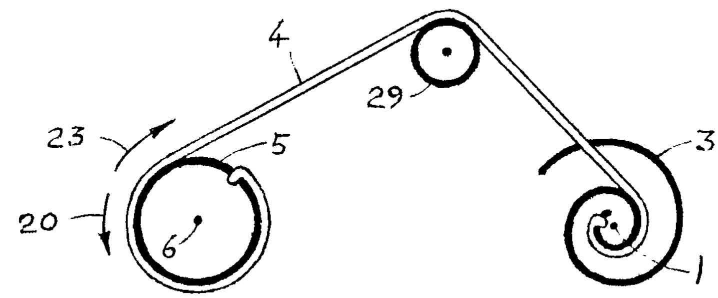


Figure 15

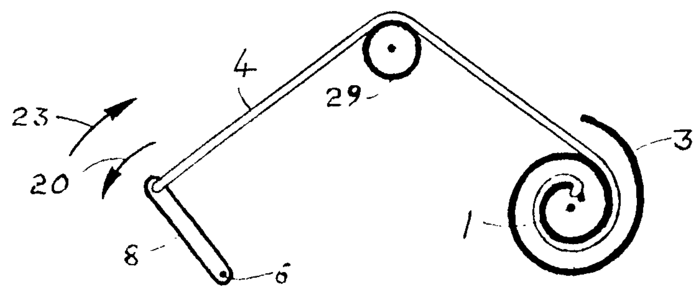
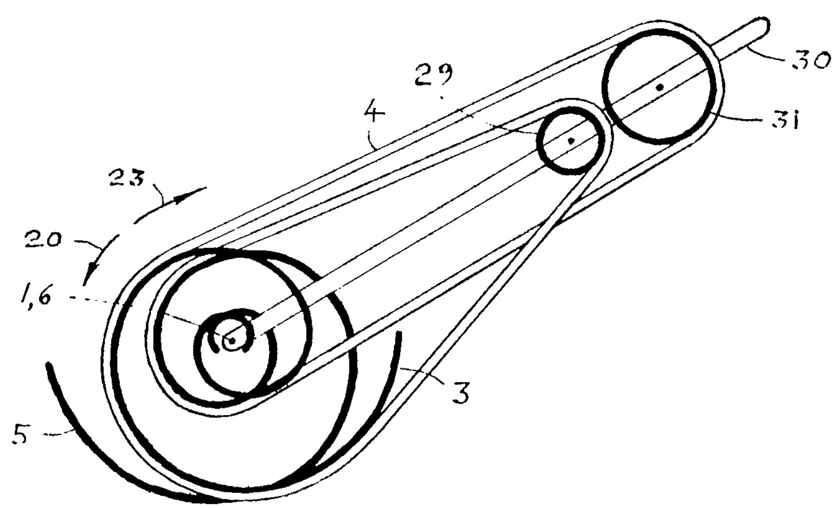


Figure 16



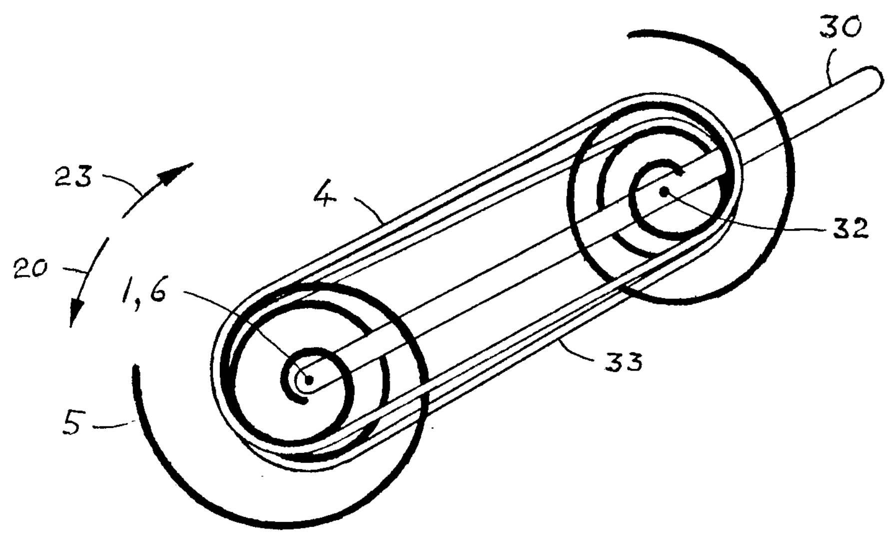


FIGURE 17

SPECIFICATION

Variable-ratio transmission

This invention relates to a variable-speed-ratio mechanical power transmission suitable for man-powered, animal-powered and other relatively low-speed highly stressed applications. The transmission is intended to provide the following advantages.

a Continuously variable ratio of output speed to input speed
b Ratio variable over a wide range
c Ratio variable under load
d Positive slip-free drive providing high efficiency
e Output speed steady with no cycle variations (for constant input speed)
f Operation easily automated.

The output shaft of the transmission is driven by one or more variable-amplitude reciprocating ratchets, freewheels or sprag or one-way clutches. This invention is of an improved method of providing the reciprocating motion to the clutches and of varying its amplitude. According to the invention each clutch is fitted with or otherwise connected to a toothed chainwheel driven by or driving a chain and on which the teeth are arranged as a spiral, causing the length of the lever-arm of the chain about the chainwheel axis to vary as the chainwheel rotates. For a given linear amplitude in the reciprocating motion of the chain, the longer its mean lever-arm about the chainwheel axis, the smaller the angular amplitude of the reciprocating motion of the chainwheel. The gearing ratio to each clutch is thus changed by winding the chain on to more or less of the spiral. Further and optional features of the invention appear in the following description and accompanying figures and are set forth in the appended claims.

For ease of thinking an example of the device, using two parallel mechanisms, will be described as installed on a bicycle. Two one-way clutches are mounted on the output shaft 1 (the bicycle rear wheel) which they each drive in turn through a certain angle. The mechanisms driving each of the clutches are identical, mirror images of each other or otherwise similar. What follows describes the drive to one or other clutch only.

The clutch 2 is fitted with a toothed sprocket 3 driven by a chain 4 passing over it. The teeth are not arranged on the circumference of a circle but on a spiral which, by means of a slight pitch angle, is not limited to 360 degrees but can accomplish several turns, the visual effect being similar to a block of sprockets used in derailleur system but formed from a single spiral.

The front end of the chain passes over a chainwheel 5, similarly spiralled but not necessarily of the same size, mounted concentrically with the input shaft 6 (the bicycle crank axle). The chain is either continuous and in contact with each toothed spiral for approximately 180 degrees as in Fig. 1, or anchored to one end of each spiral as in Fig. 3. If the chain is continuous, either the equations defining the spirals are such that the chain is taut at all times, or the slack is taken up as in Fig. 2 by a chain tensioner 7 as seen in derailleur systems. If the chain is discontinuous as in Fig. 3, the return motion 23 of the drive is powered by a spring attached to the clutch.

Simpler alternatives are shown in Figs. 4 to 7, in which only one of the toothed wheels is a spiral. In such cases the chain may again be either continuous with a chain tensioner 7, or discontinuous with a spring-powered return stroke 23. If the chain is discontinuous, the driving chainwheel of Fig. 5 may be replaced by an oscillating arm 8 as in Fig. 8.

The driving chainwheel 5 is driven by the input shaft 6 through a mechanism which causes the chainwheel to turn forwards and backwards in turn through a certain angle. A mechanism to do this is shown in Fig. 9. A cam 9 is mounted on and fixed to the input shaft. An arm 10 pivoted at 11 carries a cam-following wheel 12. The arm swings back and forth as the cam rotates, 13 and 14 being the paths of the cam follower and of the end 15 of the arm. A link 16 ties the end of the arm to a point 17 on the chainwheel 5. 18 shows the path of this point. The chainwheel is coaxial with the input shaft and reciprocates through a larger angle than does the arm 10. If the chain is discontinuous as described above, the follower 12 is held against the cam 9 by the clutch return spring. If the chain is continuous, the cam has an outer rim 19.

As the front chainwheel 5 rotates in the forward direction 20, thus engaging the clutch and driving the output shaft, the ratio of output-shaft speed to front-chainwheel speed is continuously changing: with the spirals handed as shown in the figures the ratio increases during the course of the forward stroke. In order to obtain a constant output-shaft speed the speed of the front chainwheel must diminish during the course of the forward stroke. The equation defining the shape of the cam 9 may be such that a constant input-shaft speed results in just the right variation in front-chainwheel speed to produce a constant output-shaft speed. The speed of the front chainwheel in relation to the position of the cam is as shown in Fig. 10 (cam speed constant), in which the shaded areas 21 and 22 are equal.

The mechanism driving the second one-way clutch on the output shaft is similar to that described, with the pivot 11 aligned with the pivot of the first mechanism, but with the cam 9 displaced round the input shaft by 180 degrees with respect to the cam driving the first mechanism, or by an angle equal to 360 degrees divided by the number of parallel mechanisms. Alternatively, the pivots may be spaced regularly round the input-shaft axis and the cams be either aligned or form a single cam.

The ratio of the output speed to the input speed (the gearing ratio) is varied by moving the pivots 11 to another position on a circle concentric with the input shaft, thus winding the chains further outwards on the front pair of spirals and inwards on the rear pair, or vice versa.

If the transmission is under load, moving the two pivots together will require some force. To avoid this, the two pivots may be moved sequentially, each while its mechanism is on its return stroke 23. In this case, the equation defining the cams may be made such that the driving portion 24 of the cycle in Fig. 10 lasts for somewhat more than 180 degrees, in order to span the gap introduced by the two pivots not being moved together.

If the two pivots are to be moved together as in Fig. 11, they may both be mounted on the same wheel 25 concentric with the input shaft. This wheel may be toothed and turned or held in place by a worm 26. If the two pivots are to be moved sequentially as in Fig. 12, each may be mounted on a separate wheel 27, each controlled by a worm 28.

The single worm 26 or each of the two worms 28 may be driven manually or by an electric motor operated either manually or automatically by a device sensing the speed of whichever shaft it is desired to control: in the case of human or animal power the aim would be to keep the input speed constant irrespective of the driving force applied to the input shaft or of the load on the output shaft; in the case of wind power the aim might be to keep the input speed in proportion to the wind speed. The electric motor may be powered by a dynamo driven by whichever shaft is to have the more constant speed.

In the case of Figs. 4, 5 and 8, the gearing ratio may alternatively be changed not by moving the pivots 11 but by varying the length of the tension side of the chain, such as by moving the two chainwheels apart or by moving an intermediate idler chainwheel 29 as in Figs. 13 to 15.

If the gearing is not to be changed by moving the pivots 11, the oscillating arm B may be the same part as the arm 10 in Fig. 9, with the link 16 absent and the chain attached directly at 15. Similarly, the driving chainwheel 5 may be mounted on the pivot 11 and itself carry the cam follower 12. In such cases the driving chainwheel 5 or the oscillating arm 8 no longer rotate about the input shaft 6.

One arrangement allowing the gearing ratio to be changed with very little force even under load is shown in Fig. 16. In this case the input and output shafts 1 and 6 are coaxial and the pivots 11 are fixed. The movable idler 29 is at a fixed distance from the input and output shafts, and the gearing ratio is changed by moving the idler to another position by means of the handle 30. The handle also carries a second idler 31 for the slack side of the chain. As in Fig. 1, the equations defining the spirals in Fig. 16 may be such that the chain is taut at all times; otherwise the slack-side idler 31 may be spring-mounted on the handle 30 and function as a chain tensioner. Alternatively, as in Fig. 3, the chain may be anchored to the ends of the spirals; the slack side of the chain and its idler 31 would then be absent.

A similar arrangement is shown in Fig. 17. The input shaft 6 and output shaft 1 are concentric and the gearing ratio is changed by moving the handle about them. The one-way clutches may be either on the output shaft 1 or on an intermediate shaft 32 mounted on the handle. A second chain 33 passes over two closed chanwheels to transfer the power from the movable shaft 32 to the output shaft 1. If the clutches are on the movable shaft 32 then only one second chain 33 is required. If the clutches are on the output shaft 1, then as many second chains 33 are required as there are clutches. The primary drive, through chain 4, may be as shown in Fig. 17 or similar to any of those in Figs. 2 to 7. Alternatively, the arrangement may be inversed to that the first drive, from shafts 6 to 32, is over closed chainwheels and the second drive, from shafts 32 to 1, is spiralled. In this case, the cams 9 may be on the input shaft 6 and each drive a primary chain, or may be on the intermediate shaft 32 driven by a single primary chain from the input shaft 6. A third possibility, if a very wide range of gearing ratios is required, is to have both the primary and secondary drives spiralled, each similar to any of those in Figs. 1 to 7.

In order to lessen chain misalignment the axes of the various chainwheels and idlers in any of these examples may be made slightly nonparallel.

Any of the spirals may be of opposite handedness to that shown in the figures.

CLAIMS

1. A mechanical power transmission in which the power is transmitted through one or more reciprocating one-way clutches driven by chains and in which the ratio of output speed to input speed is varied by winding the chains further or less far round one or more spiral chainwheels.

2. A transmission according to claim 1 in which each chain is continuous and passes over two spiral chainwheels.

3. A transmission according to claim 2 in which the chainwheels are so shaped that the chains are taut at all times.

4. A transmission according to claim 1 in

which each chain is discontinuous and anchored to two spiral chainwheels or one spiral and one closed chainwheel.

5. A transmission according to claim 1 in which each chain is continuous and passes over one spiral and one closed chainwheel.

6. A transmission according to claim 1 in which each chain is discontinuous and anchored to a driving oscillating arm and a driven spiral chainwheel.

7. A transmission according to claims 1, 4 or 6 in which the return motion of each drive is powered by a spring with one end fixed and the other connected to the one-way clutch.

8. A transmission according to any of the above claims in which the driving and driven chainwheels are concentric.

9. A transmission according to claims 1, 2, 5 or 8 in which any slack is taken up by chain tensioners.

10. A transmission according to any of the above claims in which each driving chainwheel or arm carries a cam follower which follows a cam driven by the input shaft.

11. A transmission according to any of claims 1 to 9 in which each driving chainwheel or arm is linked to an arm carrying a cam follower following a cam driven by the input shaft.

12. A transmission according to claims 10 or 11 in which the cams are so shaped that a constant input speed produces a constant output speed.

13. A transmission according to claims 11 or 12 in which the driving chainwheels or arms are concentric with the cams.

14. A transmission according to claim 13 in which the gearing ratio is changed by moving the pivots of the arms about the centre of the cams.

15. A transmission according to any of claims 1 to 13 but not 3 in which the chain passes over an idler chainwheel by moving which the gearing ratio is changed.

16. A transmission in which the input and output shafts are concentric and in which the power is transmitted according to any of claims 1 to 13 but not 6 or 8 to or from or to and from one or more intermediate shafts by moving which the gearing ratio is changed.

17. A transmission according to claims 14, 15 or 16 in which the pivots, idlers or intermediate shafts are all moved together.

18. A transmission according to claim 17 in which the pivots, idlers or intermediate shafts are all connected to the same toothed wheel controlled by a worm gear.

19. A transmission according to claims 14, 15 or 16 in which the pivots, idlers or intermediate shafts are moved sequentially.

20. A transmission according to claim 19 in which each pivot, idler or intermediate shaft is connected to its own toothed wheel controlled by its own worm gear.

21. A transmission according to any of claims 1 to 13 but not 3 or 8 in which the gering ratio is changed by varying the distance between the driving chainwheel or arm and the driven chainwheel.

22. A transmission according to any of the above claims in which the chains are replaced by ropes or belts and the chainwheels by pulleys.

23. A transmission according to any of the above claims in which the gearing ratio is changed automatically by a mechanical governor or electronic device sensing the input or output speeds or loads or other external conditions.

24. A transmission according to any of the above claims in which any of the axes of rotation are nonparallel.

25. A transmission according to claim 1 incorporating any of the features described in the accompanying text or figures.

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