

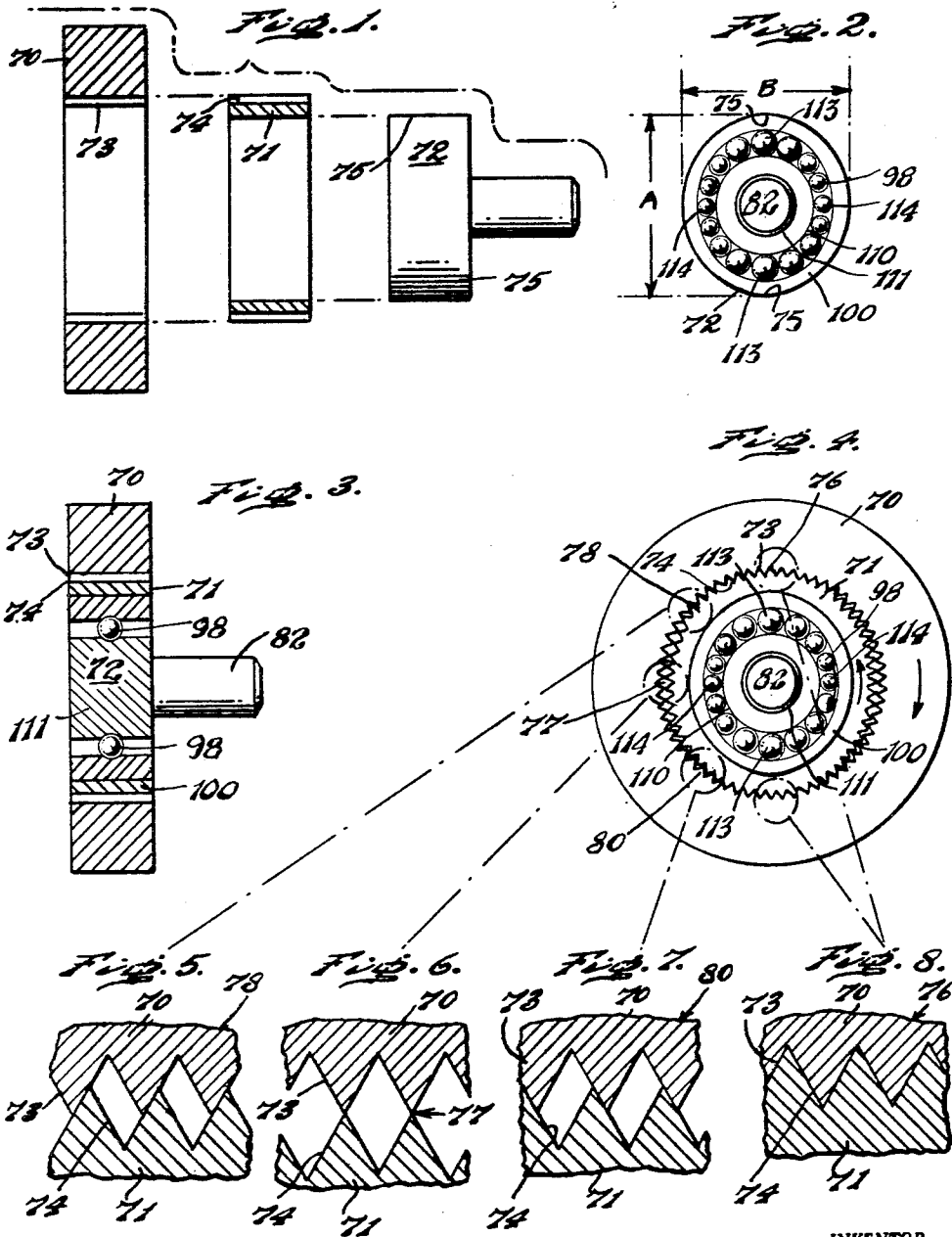
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STRAIN WAVE GEARING-BEARING VARIABLE ELEMENTS

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STRAIN WAVE GEARING-BEARING VARIABLE ELEMENTS

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Original application March 21, 1955, Serial No. 495,479, now Patent No. 2,906,143, dated September 29, 1959. Divided and this application March 23, 1959, Serial No. 801,194

4 Claims. (Cl. 74-640)

The present invention relates to motion transmitting mechanism, and particularly to gearing in which relative motion occurs between an internal gear and a cooperating external gear.

The present application covers the species of my parent application Serial No. 495,479, filed March 21, 1955, for Strain Wave Gearing, now United States Patent No. 2,906,143, issued September 29, 1959, which relates to the strain inducer utilizing a bearing having bearing elements of varying diameters and is a division of such application. The parent application is incorporated herein by reference. The reader is referred to this patent for understanding of the background and of the theory.

The species of the parent application relating to the dual form and to the electromagnetic strain-inducer is embodied in my copending application Serial No. 656,572, filed May 2, 1957, for Dual Strain Wave Gearing.

A purpose of the invention is to secure relative motion between cooperating internal and external gears, by propagating a strain wave which advances an area of contact or preferably a plurality of areas of contact between the respective gears.

A further purpose is to transmit a strain wave to a strain gear through the medium of an antifriction bearing having balls of different sizes which create the lobes in the strain inducer.

Further purposes appear in the specification and in the claims.

In the drawings I have chosen to illustrate a few only of the numerous embodiments in which my invention may appear, selecting the forms shown from the standpoints of convenience in illustration, satisfactory operation, and clear demonstration of the principles involved.

Figure 1 is an exploded axial section of a device for transmitting motion according to the present invention, in a simplified form.

Figure 2 is a right end elevation of the strain inducer shown in Figure 1.

Figure 3 is an axial section corresponding generally to the exploded section of Figure 1, but showing the parts assembled in their normal operating relationship.

Figure 4 is a right end elevation of the assembly of Figure 3.

Figures 5 to 8 inclusive are enlarged developed fragmentary sections transverse to the axis showing the relative relations of the teeth at various positions in Figure 4, as indicated by the corresponding section lines.

Describing in illustration, but not in limitation and referring to the drawings:

General features of invention

The present invention is concerned with eliminating difficulties encountered in conventional gearing, as will

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be explained more in detail later. The present invention deals particularly with gearing of a character in which inner and outer concentric gears are brought into mating relationship in a plurality of spaced areas, with interspersed areas in which they are not in mating relationship, and the areas of mating relationship are propagated forward in a wave which for the purposes of the present invention is described as a strain wave, since it represents a wave deflection in one of the gearing elements.

This strain wave is actually superimposed on the circumference of one or both of the gears, and travels with respect to it at a rate which is determined by the rate of application of load or rotatory force to the mechanism.

It should be appreciated that in the mechanism of the present invention, unlike all ordinary gearing, two cooperating gears move into and out of tooth engagement by radial motion of the teeth of one gear with respect to the other, without in the least necessitating any change in the gear axis. It will be evident, therefore, that this action presupposes a motion of parts of one of the gears with respect to other parts which can be accomplished in any suitable manner, but preferably will be achieved by deflecting an elastic material, which may be for example an elastomer such as rubber, synthetic rubber, nylon, or other plastic, or a metal such as steel, bronze, or other gear material, moving within the elastic limit, and thereby substantially free from plastic deformation.

Principles of operation

Strain wave gearing is a novel system for transmitting motion and power in which the gear tooth engagement is induced at a plurality of points by the deflection of a thin ring gear or the like. The tooth engagement at a plurality of points around the circumference is propagated along the periphery of the thin ring gear as the crest of the induced deflection wave is made to move around this periphery. As the deflection moves around the gear, each tooth moves radially in and out of engagement as it progresses from one tooth to the next, tracing during this motion a curve which is generally of the character of a sinusoidal wave, giving rise to the term "strain wave gearing."

In the simplest form as shown for example in Figures 1 to 8 inclusive, the motion transmitting device consists of a ring gear 70, a strain gear 71, and a strain inducer 72. The ring gear has internal teeth 73 in the illustration shown, which are preferably of axially extending character. In this form the strain gear 71 has external teeth 74 which also preferably extend axially and at the same diametral pitch as the teeth on the ring gear but have a slightly smaller pitch diameter. This difference in pitch diameter is caused by the fact that the number of teeth in this case on the strain gear is less than the number of teeth on the ring gear. The difference in the number of teeth between the two gears, or the tooth differential, should be equal to or a multiple of the number of places at which the strain gear is deflected to cause tooth engagement with the ring gear. This differential would desirably be two, using a strain inducer having an elliptical contour with two lobes 75, as shown in Figures 1 and 2. As already explained, the strain gear 71 is made of a material which is elastic under the conditions of operation, and in the case of a steel strain gear, is made of relatively thin cross section so that it can be deflected easily in a radial direction.

The form of strain inducer for transmitting motion as illustrated in Figures 1 to 8 is a very simple one having two points of strain engagement of the strain gear. The

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strain inducer 72 has an elliptical contour, as already explained, whose major axis A is larger than the inside diameter of the strain gear 71 by an amount approximately equal to the difference in pitch diameter of the ring gear and the strain gear. The minor axis B is smaller than the inside diameter of the strain gear by approximately the same amount. When the strain inducer is inserted into a position inside the strain gear, as shown in Figure 3, it causes the strain gear to be distorted into elliptical form, with the pitch line of the teeth at the major axis equal to the pitch diameter of the ring gear as shown at 76 in Figures 4 and 8. At the position as shown in Figure 8 the pitch circles of the two gears are coincident. At the minor axis the pitch line of the strain gear teeth is smaller than the pitch diameter of the ring gear, and if a full tooth height is used, the teeth will just clear one another as shown at 77 in Figures 4 and 6. At intermediate points 78 and 80 as shown in Figures 4, 5 and 7, the teeth will have varying degrees of engagement. This condition prevails where the tooth differential is equal to the number of lobes on the strain inducer which in this case is two.

The number of lobes in the strain inducer is designated by n in the equation referred to in the patent aforesaid, and the difference in the number of teeth is equal to n or a multiple thereof. The number of lobes in most cases will be two or three.

In the embodiment of the present application a strain inducer shaft 82 turns and has at one end within the strain wave gearing a circular arbor 111 mounted rigidly thereon which is provided at the outside with a circular antifriction bearing race 110. While the antifriction bearing elements shown herein are balls, it will be evident from my patent aforesaid that the antifriction bearing elements may be balls or rollers as required. Where self centering is not required, it will be normal to use two lobes; in the strain inducer under discussion two lobes rather than three lobes are shown.

By using an antifriction bearing as employed in the present application, the coefficient of friction can materially be reduced with a resulting increase in efficiency.

Around the race 110 ball bearing balls 98 travel, which vary in size to produce the desired deflection and wave form in a cooperating outside deflectable race 100 which has an oval contour as best seen in Figures 2 and 4. In the two lobe form there are large balls 113 at the lobes and these grade down to minimum ball sizes at 114 intermediate between the lobes.

For best results it is preferable to use not less than 36 balls, and the two balls immediately adjacent to the largest ball at the lobe should be slightly oversized to distribute the initial deflection load on three balls at the lobe in the preferred form. The rest of the balls should be of such a size that they will have no more than 0.001" clearance. Under load the clearance on one side of the wave will disappear and all of the clearance will be centered at the opposite side of the wave. The use of a ball retainer is optional but it may be desired for long life and high speed.

In a bearing of this type the smaller balls have the greatest planetary speed. This will cause the load carrying balls to separate under load and tend to eliminate ball to ball friction. Where the small ball would tend to overtake the large balls, the bearing is not under load and the balls have clearance with the raceway. Again, however, the change in load on the individual balls caused by separation will change the ratio of these balls to the raceways at the interface between the ball and the surfaces on which it rolls. This is caused by the localized tangential shear stress from the ball rolling into a wedge-shaped opening. This action will tend to prevent excessive separation of the balls, particularly under heavy load. With this type of strain inducer, no adjustment can be made in the deflection and consequently the two

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gears must be made to close tolerances. A strain inducer of this type appears particularly suited to quantity manufacture of power transmission equipment where the gears are broached and no adjustments are needed. It of course requires a special bearing which however is a simple problem in quantity production.

It will be evident that since the balls engage the races, the turning of the inner arbor turns the balls and this causes a wave of deflection to travel around the outer race and to deflect the flexible gear 71, sending a wave around that gear.

The outer race should be thin enough to prevent it from being stressed beyond the endurance limit.

For a discussion of the three lobe form, the reader is referred to my patent above referred to.

In view of my invention and disclosure, variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art to obtain all or part of the benefits of my invention without copying the structure shown, and I, therefore, claim all such insofar as they fall within the reasonable spirit and scope of my claims.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. In a device for transmitting motion, a first gear, a second gear of different diameter from the first having teeth of the same size as the first gear concentric therewith and having a deflectable wall, a strain inducing element operative to deflect the second gear, and maintaining the second gear deflected into mating relation of its teeth with the teeth of the first gear on the concentric axis at a plurality of circumferentially spaced positions interspaced by nonmating positions, the strain inducing element comprising a first raceway engaging one circumferential surface of the second gear, a second raceway cooperating in spaced relation with the first raceway, and bearing elements of variant diameters and at least two equally circumferentially spaced diametral maxima interposed between and traveling in the first and second raceways for propagating a strain wave in the second gear, and means for moving the operative relationship of the strain inducing element relative to the periphery of the second gear and thereby propagating a strain wave around the periphery of the second gear and causing relative rotation of the second gear with respect to the first gear.

2. In a motion transmitting device, inner and outer antifriction bearing raceways cooperating with one another and antifriction bearing elements in the raceways varying in diameter and having at least two equally circumferentially spaced diametral maxima, in cooperation with cooperating gears one of which is flexible and one of which is interior and the other exterior, said flexible gear being in motion transmitting relationship with one of said raceways so that it is subjected to a wave motion imparted by the raceway.

3. In a motion transmitting device, inner and outer antifriction bearing raceways, one of which raceways is of elliptical form, and antifriction bearing elements in the raceways of progressively varying diameter and having at least two circumferentially equally spaced diametral maxima.

4. In a device for transmitting motion, a first tooth member, a second tooth member of different diameter from the first having teeth adapted to cooperate with those of the first member, concentric with the first member and having a deflectable wall, a strain inducing element operative to deflect the second tooth member, and maintaining the second tooth member deflected into mating relation of its teeth with the teeth of the first tooth member at a plurality of circumferentially spaced positions interspaced by nonmating positions, the strain inducing element comprising a first raceway engaging one circumferential surface of the second tooth member, a second raceway cooperating in space relation with the first raceway,

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and bearing elements of variant diameters and at least two equally circumferentially spaced diametral maxima interposed between and travelling in the first and second raceways for propagating a strain wave in the second tooth member, and means for moving the operative relationship of the strain inducing element relative to the periphery of the second tooth member and thereby propagating a strain wave around the periphery of the

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second tooth member and causing relative motion of the second tooth member with respect to the first tooth member.

References Cited in the file of this patent

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