HARMONIC NOZZLE DRIVE

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Filed: Sept. 20, 1974

Appl. No.: 507,809

U.S. Cl. 239/227; 239/240
Int. Cl. B05B 3/00; B05B 3/04
Field of Search 239/227, 240

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ABSTRACT

Surface cleaning equipment comprising a housing containing a fluid driven impeller and a closed chamber through one end of which passes an impeller-driven shaft and through the opposite end of which passes an output shaft which drives an orbital spray nozzle receiving the impeller exhaust fluid from a housing passage outside the chamber, the output shaft being driven at reduced speed by transmission of the impeller shaft rotation through a wave generator-harmonic drive gear mechanism contained in the chamber.

11 Claims, 6 Drawing Figures
HARMONIC NOZZLE DRIVE

BACKGROUND OF THE INVENTION

The general kind of cleaning equipment with which the invention is concerned and as typified in U.S. Pat. No. 3,416,732, issued Dec. 17, 1968, entitled WASHING APPARATUS FOR ENCLOSED SPACES, employs the general combination of a housing containing a fluid driven impeller the output shaft of which drives one or more nozzles in an orbital path about the housing axis and which receive the impeller water or cleaning solution effluent.

Harmonic drive mechanisms which are the subject of U.S. Pat. No. 2,906,163 issued Sept. 29, 1959 to C. W. Musser on Strain Wave Gearing, are known to utilize a traveling wave generated in a flexible endless component and the motion conversion that results from an advancing wave shape.

A non-rigid mechanical element is used for the generation of a continuous deflection wave capable of achieving a very high mechanical leverage and of transmitting rotary and linear forces through steel walls. Theory conversion to practical usefulness in harmonic drives is accomplished by using three basic elements; a circular spline, a flexspline and a wave generator. While these elements may take alternate forms in units designed for special application, the type herein shown is representative of the form useable for the present invention.

In the basic harmonic drive configuration, the wave generator is the input element. It imparts an ellipse-like shape to the non-rigid flexspline that normally functions as the output element. The circular spline is a rigid circular fixed member with internal teeth that are progressively meshed with those of the flexspline by the wave generator.

The difference in relative rotary motion is due to the difference in the number of teeth between the flexspline and the circular spline. The reduction ratio, \( R \), of a harmonic drive transmission is determined by the formula:

\[
R = \frac{N_s}{N_f - N_c}
\]

wherein \( N_s \) is the number of teeth in the flexspline and \( N_c \) is the number of teeth in the circular spline. Teeth on the flexspline and circular splines are cut to the same circular pitch with the smaller internal flexspline carrying slightly fewer teeth than the circular spline. This will make the above ratio, \( R \), have a negative value which means that the flexspline and wave generator turn in opposite directions.

Advantages of the harmonic drive are high speed reduction in a single stage along with high torque capacity relative to the size and weight of a unit. Spline teeth come into contact almost by pure radial motion and have essentially zero sliding velocity, making friction and wear losses almost negligible. Advantages from this feature make high mechanical efficiencies at high ratios possible, because the spline tooth contact under load is practically stationary, permissible dynamic loading under normal operating conditions make it possible to transmit torques more nearly proportional to the static strength of the spline teeth. Under load, more than one set of spline teeth are in simultaneous engagement resulting in high torque capacity. Teeth adjacent to load bearing teeth are in near engagement which provides resistance to shock overloads. Regions of tooth engagement and application of load torque are diametrically opposed, resulting in a force couple that is symmetrical and balanced. Concentricity of the elements tend to make the harmonic drive self-aligning.

SUMMARY OF THE INVENTION

The invention has for its general object to employ the harmonic drive principle in a new environment and manner as a speed reducing transmission between an impeller driven shaft and an output shaft which drives one or more washing or spray nozzles, thus to improve the control, stability and efficiency of the washing operation.

More particularly the invention contemplates cleaning equipment comprising a housing having a fluid inlet and containing a fluid driven impeller from which the fluid flows through a passage in the housing, harmonic speed reducing mechanism interposed in effect between the impeller shaft and a nozzle drive shaft receiving the impeller effluent from the housing fluid passage.

In its preferred form the invention provides within the housing a closed chamber spaced therefrom to define the fluid passage and receiving through one end the impeller shaft which drives a wave generator operating within a flexible gear or flexspline having teeth contacting the differentially numbered teeth of a rigid gear mounted to the chamber wall, the flexspline being connected through the bottom of the chamber with the reduced speed nozzle shaft.

Particularly adaptable to efficient structure and operation of the invention is the use of a harmonic drive transmission in which the flexspline has the form of a radially flexible cup, the open end of which receives the wave generator inside the flexible gear and the opposite or closed end of the cup being connected to the nozzle rotating shaft.

These and additional features, objects and details of the invention will be more fully understood from the following detailed description of an illustrative embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view showing the cleaning apparatus in vertical medial cross section;
FIG. 2 is a section looking upward as viewed from line 2—2 of FIG. 1;
FIG. 3 is a view in the same plane looking downward;
FIG. 4 is an enlarged cross section on line 4—4 of FIG. 1;
FIG. 5 is a fragmentary vertical section taken on line 5—5 of FIG. 4; and
FIG. 6 is an exploded perspective showing the harmonic drive parts.

DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENT

Assuming the apparatus to be vertically oriented as in FIG. 1, the assembly is shown to comprise a housing 10 the tubular body 11 of which is connected by head 12 and pipe or hose coupling 13 to pressurized water or cleaning solution source. Bottom 14 of the body mounts the spray nozzles as will appear. Inlet disc 15
secured to head 12 by screws 16 contains angular openings 17 (see FIG. 2) registering with inlet holes 18 and which direct the liquid against vanes 19 carried by the impeller 20 to produce its rotation.

The housing contains an axially aligned closed chamber, generally indicated at 21, which may be rendered water tight by appropriate use of seals. The chamber is defined by its wall 22 which is annularly spaced at 23 from the housing shell 11 to form a passage for the impeller effluent going to the nozzles as will appear. The chamber 21 has a top closure 25 secured to the wall 22 by screws 26 and contains a central opening 27 through which passes the impeller shaft 28 within seal ring 29 and bearing 30.

The impeller drive is transmitted to the orbiting nozzle 31 by way of reduced speed flex spline adaptor shaft 32b connected to output shaft 32 by screw 24 and extending through the lower ends of both housing 10 and chamber 21 within bearings 33 and 34 and seal rings 35, 36. Lower tubular extent 32a communicates through its openings 37 with annular space 38 which connects with passage 23 through one or more openings 39. The bottom shaft extent 32a is threaded at 40 within T fitting 41 into which is threaded tubular lateral 42 which mount bevel gears 43 for rotation on bearings 44 in planetary relation with gears 45 secured to the housing part 14 by screws 46. The laterals 42 also mount the nozzle bodies 47 which are fixed to gears 43 for rotation on bearings 48, 49. Thus the liquid is delivered through the shaft and lateral passages 50 and 51 to the nozzles traveling an orbital path about the housing axis. Handle 52 may be provided for manipulation of the unit.

Turning now to the harmonic drive transmission generally indicated at 54 and as particularly shown in FIGS. 4, 5 and 6, its components include a collar coupling 55 having flange 56 and drilled hole at 57 to receive pin 58 to key the coupling against rotation on the impeller shaft 28. Externally the coupling may have a snap ring groove 59 and internally the coupling has diametrically slotted ways 60 for reception of key lugs 61 projecting inward from locking ring 62 and diametrically opposed key lugs 61a at right angles to key lugs 61 on lock ring 62 extending through key ways 63 in the wave generator 64. The described assembly is held in its FIG. 5 relation by retaining ring 65 and snap ring 66. Wave generator 64 is thus interlocked with the impeller shaft for rotation therewith at its speed.

The wave generator rotates within a force transmitting bearing assembly generally indicated at 67 and comprising radially flexible raceways 68 and 69 for the bearings 70. Raceway 69 is adhered to the inside open flexible mouth of cup shaped flex spline 71 to the bottom of which is connected the flex spline adaptor shaft 32b by screws 72 passing through clamp ring 73. Flex spline adaptor shaft 32b is connected to the output or driver shaft 32 by screw 24. Needle bearings 74 may be provided to journal the impeller shaft terminal radially.

Adhered to the outside of the flex spline mouth is a radially flexible gear 75 the teeth 76 of which are contactable with the teeth 77 of circular rigid gear 78 held to the chamber 21 wall 22 by screws 26. Bearing retaining ring 79 is connected by screws 80 to the wave generator for rotation therewith in overlying relation to the bearing assembly 67. As particularly shown in FIG. 4 the wave generator 64 by reason of its elliptical shape operates to deflect the flexible bearing 67, i.e., its race rings 68 and 69, the wall of flex spline 75 and its teeth 76 in an elliptical progression or wave so that the flexible and rigid gear teeth 76 and 77 are caused to interengage from their opposed clearances at 81 along their opposed engaged courses at 82. Gear 78 being held stationary the flex spline gear becomes rotated by virtue of the fewer number of gear teeth than gear 78 and in a direction opposite the rotational direction of the impeller shaft 28.

Typically the rigid and flexible gears may be cut to pitch diameter of about 2.06 inches with rigid gear having 162 to 322 number of teeth and the flexible gear carrying 160 to 320 teeth. In this ratio the output shaft 32 will be driven in a reduced speed within the range of about 50 to 200 to 1 rpm of the impeller shaft which may be assumed to rotate from 5000 - 20000 rpm depending on the quantity of fluid passing through impeller 20. Thus the speed ratio may be in the range of about 0.5 to 2% of the impeller rotary speed. Chamber 21 may contain a suitable lubricant for the gears and other rotating parts contained therein.

I claim:
1. Drive for an orbital nozzle comprising a housing having a fluid inlet and containing a fluid driven impeller from which the fluid flows through a passage within the housing, harmonic rotary speed reducing mechanism in the housing comprising an inner relatively flexible rotating gear having teeth meshing with the differentially numbered teeth of an outer relatively rigid gear, a rotating wave generator driven by said impeller and operable to flex said inner gear in wave sequence, an output shaft driven by said inner gear at speed reduced below the impeller speed, and means driven by said output shaft mounting said nozzle for rotation including means for delivering fluid from said passage to the nozzle.

2. Drive according to claim 1 in which said driven shaft is rotated at a speed within the range of about 0.5 to 2% of the impeller rotary speed.

3. Drive according to claim 1 in which said inner gear is joined to the open top of a gear splined cup axially centered in the housing and to the bottom of which said shaft is connected.

4. Drive according to claim 1 in which said gears are contained in a chamber through one end of which passes a shaft driven by the impeller and through the opposite end of which said driven shaft extends.

5. Drive according to claim 3 in which said gears are contained in a chamber through one end of which passes a shaft driven by the impeller and through the opposite end of which said driven shaft extends.

6. Drive according to claim 4 in which said chamber is water tight and contains a gear lubricant.

7. Drive according to claim 4 in which said chamber is contained within the housing and said passage is between the chamber and housing.

8. Drive according to claim 7 in which said inner gear is joined to the top of a radially flexible cup depending within the chamber and to the bottom of which said output shaft is connected.

9. Drive according to claim 8 in which said wave generator rotates within and flexes said cup and flexible gear in an elliptical course.

10. Drive according to claim 9 in which the impeller driven shaft extends through the bottom of said cup.

11. Drive according to claim 10 in which the impeller shaft is journal for rotation within said output shaft.

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