Nov. 4, 1941. F. W. DAVIS 2,261,143

GEAR

Filed Aug. 18, 1939 2 Sheets-Sheet 1

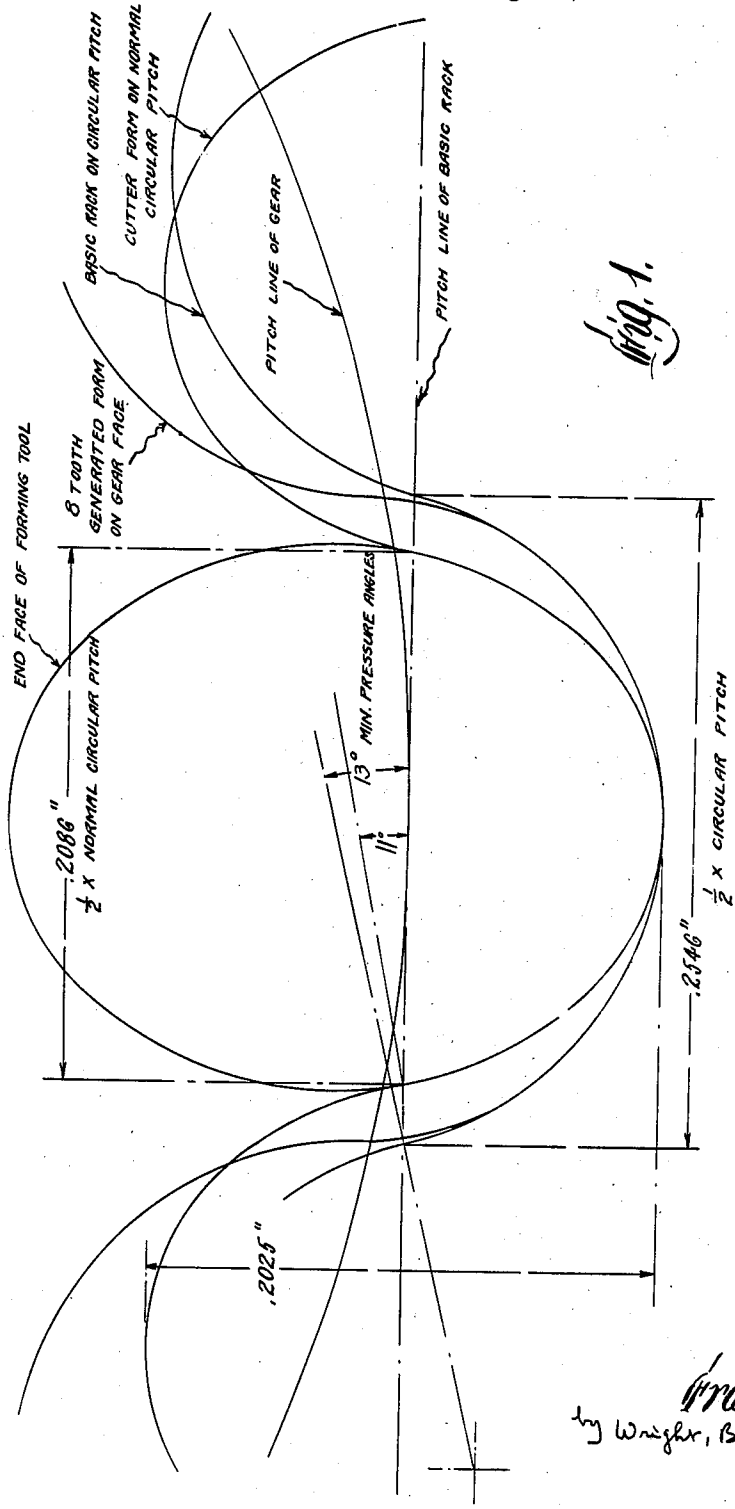


Fig. 1.

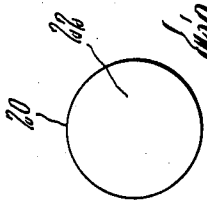


Fig. 3.

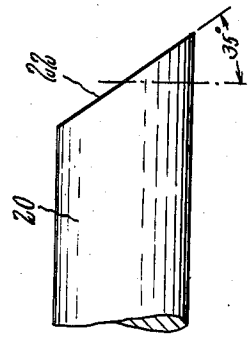


Fig. 2.

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GEAR

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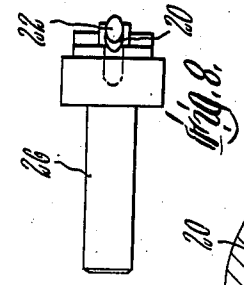


Fig. 8.

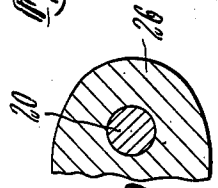


Fig. 9.

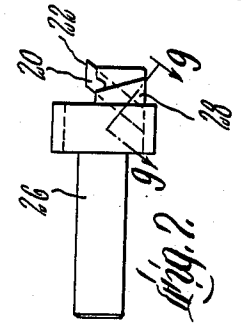


Fig. 2.

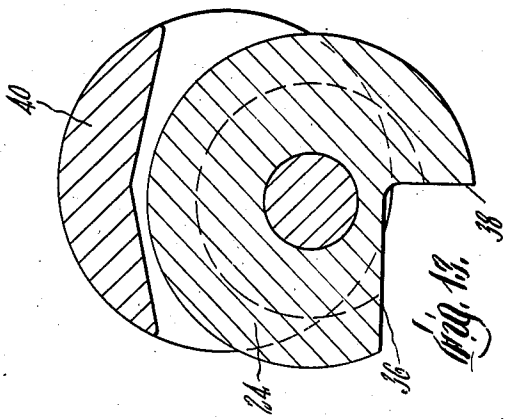


Fig. 13.

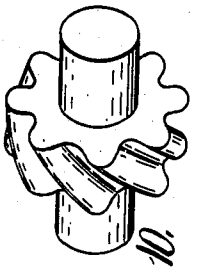


Fig. 10.

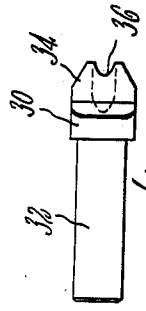


Fig. 5.

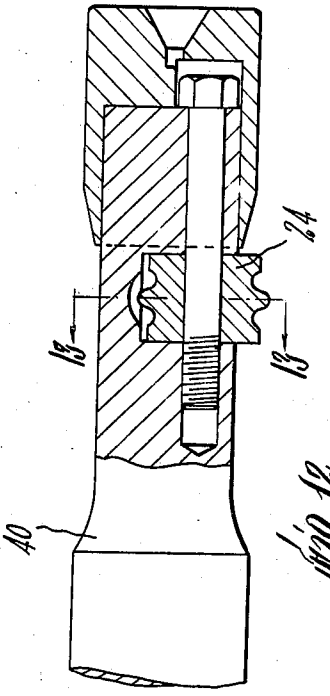


Fig. 12.

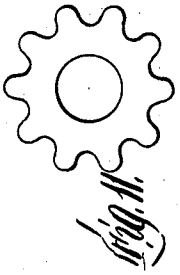


Fig. 11.

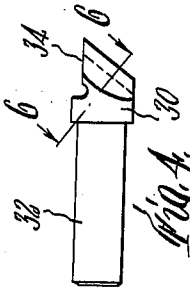


Fig. 4.

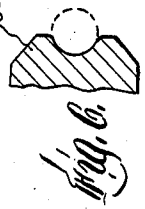


Fig. 6.

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UNITED STATES PATENT OFFICE

2,261,143

GEAR

Francis W. Davis, Belmont, Mass.

Application August 18, 1939, Serial No. 290,824

10 Claims. (Cl. 74—466)

This invention relates to an improved gear for use in a gear pump or motor, especially a pump or motor intended for service which may require satisfactory operation through a wide range of speeds. An object of the invention is to provide gears which will operate smoothly, quietly and efficiently not only at low and intermediate speeds, but also at high speeds, that is, at speeds considerably in excess of 2000 revolutions per minute. It is another object of the invention to provide a pair of gears for a pump or motor such that one gear will be driven solely by its engagement with the other. It is a further object of the invention to provide a gear pump which will operate smoothly at high speeds with maximum delivery of liquid and minimum loss by leakage from the high pressure side of the pump back to the low pressure side.

For smooth operation of the gear pump at high speeds, it is essential that there be no trapping of liquid between the meshing teeth and that the tooth form be such as to deliver a uniform flow of liquid, free from pulsations. Otherwise the pump becomes noisy at high speeds, the liquid tends to heat, and the rate of delivery of the pump eventually reaches a maximum beyond which it does not go, regardless of further increases in the speed of rotation of the pump gears.

The ideal tooth form for pumping purposes must have a continuous and closed line of action which will lie inside of the outline of the tooth profile. Such a tooth form will maintain a continuous seal or contact at the gear mesh on a single pair of mating teeth, and trapping will be impossible.

The full cycloidal and segmental tooth forms are two which meet this requirement. In order to make these self-driving, it is necessary to make them with helical teeth so that at all phases of the tooth-mesh the pressure angle at some point along the face of the gears is suitable to drive effectively. As the segmental form is simpler to manufacture than the cycloidal, it offers definite commercial advantages over the latter. The capacity of pumps having teeth of these kinds, i. e. full cycloidal or segmental, is equal to the volume of liquid carried around in the spaces between the gear teeth. If the helix angle is chosen so that the advance across the face of the rotors is one tooth interval, then the rate of delivery of the liquid will be uniform because all phases of the tooth mesh will exist at any instant at the different points across the face of the rotors.

The capacity of the gear pump, that is, the volume of liquid delivered with each revolution of the gears, is of great practical importance, particularly in cases where the weight of the pump must be kept a minimum. In gear pumps having gears of the segmental type and of a given diameter, the capacity is determined by the tooth depth, and the tooth depth is related to the minimum pressure angle, an increased tooth depth resulting in a decreased minimum pressure angle. Hence it is desirable to make gears with the smallest practical minimum pressure angle, but if the minimum pressure angle be too small, undercutting of the teeth and trapping result therefrom and the performance of a pump with such teeth is unsatisfactory, especially at high speeds.

According to the present invention, a pump gear is provided with a tooth form which has a continuous and closed line of action inside of the outline of the tooth profile and which operates satisfactorily at high speeds of rotation and delivers a relatively large volume of liquid. This gear has helical teeth with a normal profile conjugate to a basic rack of which the tooth profile is elliptical, the major axis of the ellipse being perpendicular to the pitch line. The elliptical shape gives greater tooth depth and consequently greater pump capacity than the corresponding segmental shape.

The invention also includes an improved and simplified method of and means for cutting elliptical gear teeth as hereinafter described.

For a more complete understanding of the invention, reference may be had to the following description thereof, and to the drawings of which—

Figure 1 is a diagram of profiles and related curves illustrating characteristics of an eight-tooth gear embodying the invention.

Figure 2 is a side elevation, on an enlarged scale, of a forming tool for making a gear cutter.

Figure 3 is an end view of the tool shown in Figure 2.

Figure 4 is a side elevation of a forming tool for shaping the convex edges of the cutter.

Figure 5 is a plan view of the same.

Figure 6 is an enlarged section on the line 6—6 of Figure 4.

Figure 7 is a side elevation of a forming tool consisting of the cylindrical element shown in Figure 2 and a holder therefor.

Figure 8 is a plan view of the same.

Figure 9 is an enlarged section on the line 9—9 of Figure 7.

Figure 10 is an isometric view of an eight-tooth pump gear embodying the invention.

Figure 11 is an end elevation of a ten-tooth gear embodying the invention.

Figure 12 is a fragmentary side elevation of a cutter arbor, part being broken away to show a cutter in section.

Figure 13 is an enlarged section on the line 13—13 of Figure 12.

By way of example, the drawings illustrate the characteristics of an eight-tooth gear embodying the invention, and tools by which such a gear may be easily and accurately produced, but the invention is not limited to gears of any specific number of teeth. A finished gear is illustrated in Figure 10, this gear being characterized by the following features. Its helix angle is so related to its axial length that the face profile of each tooth at one end is axially alined with the face profile of the next tooth at the other end. Thus the angular advance of the helix from one end face of the gear to the other is one full tooth interval. As a result, every phase of tooth engagement is present at every instant when two such gears are in mesh. The normal profile of the teeth of the gear shown in Figure 10 is conjugate to a basic rack composed of portions of ellipses. The face profile of these teeth is conjugate to a basic rack which is segmental, that is, composed of arcs of circles.

Gears having the foregoing characteristics can be conveniently and accurately made in the following manner. The pitch diameter and number of teeth for the gear are arbitrarily adopted. If a helix angle is then selected, the corresponding axial length of the gear can be computed which will keep one pair of mating teeth in contact with each other at the pitch point along the helix for an angular distance practically equal to one tooth interval. A value for the minimum pressure angle is adopted. From the foregoing values the circular pitch is readily calculated by dividing the pitch circumference by the number of teeth. The form radius is then found by dividing one-fourth of the circular pitch by the cosine of the minimum pressure angle. Multiplying the form radius by the cosine of the helix angle gives the tool point radius.

A forming tool may now be made by taking a cylinder with a radius equal to the tool point radius calculated as described. This cylinder is then slabbed off at an angle equal to the helix angle. The slabbed face is an ellipse having a major diameter equal to twice the form radius of the tooth.

By way of example, Figures 2 and 3 show a forming tool for an eight-tooth gear, consisting of a cylinder **20** having an end slabbed off at an angle of 35° to form an elliptical end face **22**. This forming tool is used to cut the grooves in a cutter **24** (Figures 12 and 13) by means of which the gear is generated as hereinafter described. To this end, the cylinder **20** may be securely mounted in a suitable holder **26** having a block **28** drilled to receive the cylinder so that the slabbed end face **22** will be perpendicular to the cutting movement of the tool. A complementary tool may be made by drilling a hole through the block **30** of a holder **32** at an angle of 35° to the long axis of the holder, the hole having a diameter equal to that of the cylinder **20**. The block is then cut away as indicated in Figure 6 to leave a little less than half the original hole. A face **34** of the block is made accurately parallel to the long axis of the holder so that the intersection of the hole with this face forms a concave elliptical edge **36** exactly complementary to the convex elliptical edge of the end face **22** of the cylindrical forming tool. This concave edge is used to cut the ridges on the cutter **24**.

By means of the forming tools, suitable tools for generating gears may be prepared. For example, a cutter **24** may be made, this cutter having a cylindrical shape with a cut-away portion **36** forming a cutting edge **38**. This cutting edge, as indicated in Figure 12, has the contour of a basic rack with elliptical teeth, that is, teeth having contours consisting of portions of the ellipse defined by the face **22** of the cylinder **20**. It is evident that the cutter **24** can be sharpened repeatedly without altering the contour of its cutting edge **38**. A cutter of this kind is equivalent to a one-tooth hob, and, while it is an example of one way of making gears of the kind described, it is not the only way nor the best way of making such gears commercially. Any of the known or customary methods of gear-making, suitable for this type of gear, may be employed as desired.

Cutters such as that illustrated in Figure 12 can be used to make gears of different characteristics. For example, the helix angle may be altered, thus changing the minimum pressure angle and the circular pitch, or gears may be made having a different number of teeth, in which case there is a change in the minimum pressure angle. Figures 10 and 11 illustrate gears of eight and ten teeth, respectively, in which the invention is embodied.

In order to illustrate the invention specifically, the characteristics of an eight-tooth gear have been calculated and laid out on the basis of certain arbitrarily assumed dimensions, the results being indicated in Figure 1. In this specific example, a tool point is made by slabbing off at an angle of 35° a cylinder having a radius of .107", the slabbed face thus having the shape of an ellipse, the minor semi-diameter of which is .107", the major semi-diameter being .1306". This ellipse is illustrated on a magnified scale in Figure 1 as the end face of the forming tool. An end portion of this ellipse (necessarily somewhat less than half) coincides with a portion of the cutter form, this form being that of a basic rack conjugate to the normal profile of the gear teeth. Such profile is thus composed of alternately inverted segments of the ellipse similar to the portion indicated, the long axis of these segments being perpendicular to the pitch line of the rack. In the example illustrated, the pitch line of the rack is .0294" from the center of the ellipse. This results in a minimum pressure angle of 11° for the basic rack on the normal circular pitch, or 13° for the basic rack on the circular pitch, where the helix angle of the gear is equal to the slabbing angle of the tool point so that the face profile of the gear is segmental. The tooth depth of this gear is .2025" which is .3977 times the circular pitch or .4854 times the normal circular pitch.

The foregoing figures relate to a single example of an operative gear embodying the invention. Operative gears can be made with the same tools, having a different helix angle or a different number of teeth, or both. If the helix angle differs from the slabbing angle of the tool point, the face profile of the gear will be conjugate to a basic rack having elliptical teeth. By starting with tool points slabbed at greater angles and consequently having elliptical faces of greater eccentricity, operable gears can be made having

minimum pressure angles smaller than those in the example illustrated, and consequently with ratios of tooth depth to circular pitch and to normal circular pitch materially greater than .4 and .5 respectively. There are practical considerations, such as increasing difficulty in actually making the gear, that limit the extent to which it is desirable to reduce the minimum pressure angles or to increase the helix angle. In designing any particular gear in accordance with the present invention, such considerations must be weighed against the advantages of increased tooth depth such as the increase of pump capacity.

The embodiments of the invention herein described are given by way of illustration and not of limitation. Various modifications and changes may be made therein without departing from the spirit or scope of the invention as defined in the following claims.

I claim:

1. A gear for a gear pump or motor, having teeth with normal profiles which are conjugate to a basic rack having teeth defined by portions of ellipses the major axes of which are perpendicular to the pitch line.

2. A helical gear for a gear pump or motor, having a helix angle so related to the axial length thereof that the face profile of each tooth at one end thereof is axially alined with the opposite face profile of another tooth, said teeth having normal profiles conjugate to a basic rack having teeth defined by portions of ellipses the major axes of which are perpendicular to the pitch line.

3. A helical gear for a gear pump or motor, having a helix angle such that the face profile of each tooth at one end thereof is axially alined with the opposite end face profile of the next tooth, said teeth having normal profiles conjugate to a basic rack with elliptical teeth and end face profiles conjugate to a basic rack with segmental teeth.

4. A gear for a gear pump or motor, having teeth with a normal profile which are conjugate to a basic rack having teeth defined by portions of ellipses the major axes of which are perpendicular to the pitch line, said rack having a minimum pressure angle of substantially 11°.

5. A helical gear for a gear pump or motor, having a helix angle such that the face profile of each tooth at one end thereof is axially alined with the opposite end face profile of the next tooth, said teeth having normal profiles conjugate to a basic rack having teeth defined by portions of ellipses the major axes of which are perpendicular to the pitch line, said rack having a minimum pressure angle of substantially 11°.

6. A gear for a gear pump or motor, having teeth the normal profiles of which have a tooth depth approximately equal to .4 times the circular pitch, said normal profiles being conjugate to a basic rack with elliptical teeth.

7. A helical gear for a gear pump or motor, having a helix angle such that the face profile of each tooth at one end thereof is axially alined with the opposite end face profile of the next tooth, said teeth having normal profiles conjugate to a basic rack with elliptical teeth, said normal profiles also having a tooth depth approximately equal to .5 times the normal circular pitch.

8. A helical gear for a gear pump, having a helix angle so related to the axial length thereof that the face profile of each tooth at one end thereof is axially alined with the opposite face profile of another tooth, the tooth form of said gear having a continuous and closed line of action within the outline of the tooth profile, said normal profile being conjugate to a basic rack having a minimum pressure angle of substantially 11°.

9. A helical gear for a gear pump, having a helix angle so related to the axial length thereof that the face of each tooth at one end thereof is axially alined with the opposite face profile of another tooth, the tooth form of said gear having a continuous and closed line of action within the outline of the tooth profile and a tooth depth approximately equal to .5 times the normal circular pitch.

10. A helical gear for a gear pump, having a helix angle of approximately 35° and an axial length such that the face profile of each tooth at one end thereof is axially alined with the opposite end face profile at the next tooth, the tooth form of said gear having a continuous and closed line of action within the outline of the tooth profile and a tooth depth not less than .4 times the normal circular pitch.

FRANCIS W. DAVIS.