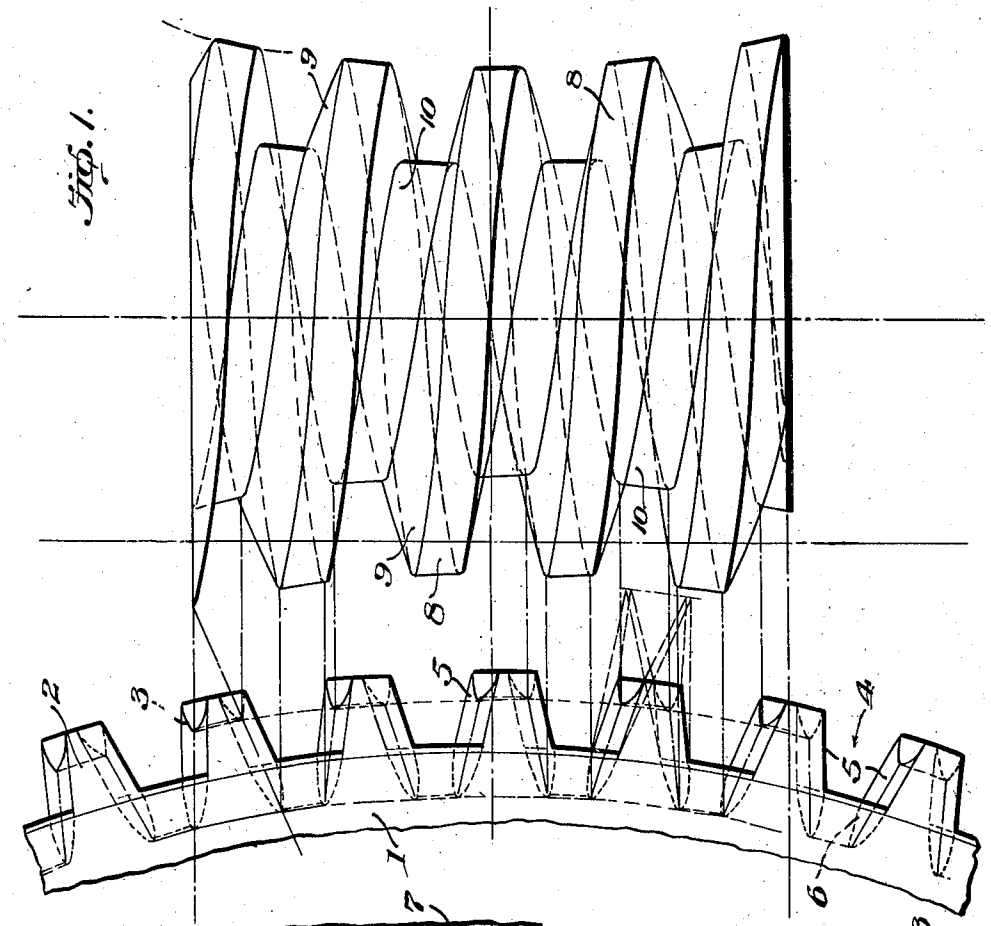
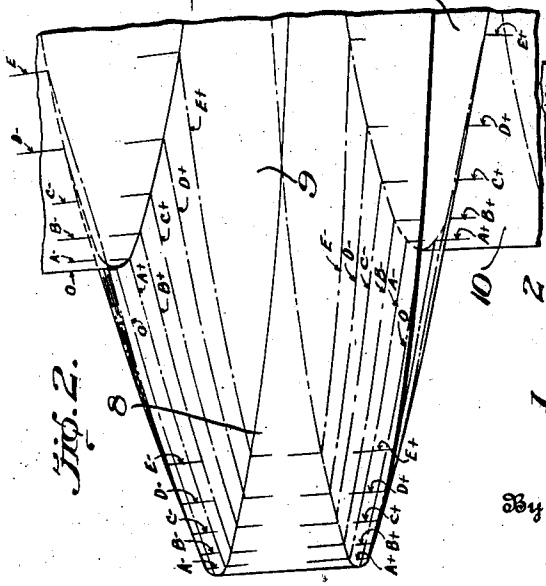
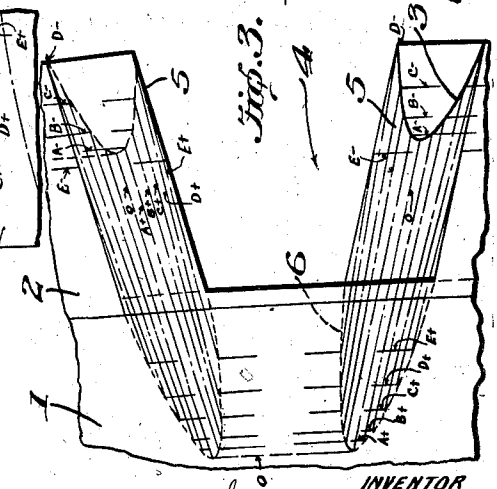
Sept. 8, 1931. S. I. CONE 1,822,800

HINDLEY WORM GEAR

Filed June 27, 1925 4 Sheets-Sheet 1







INVENTOR

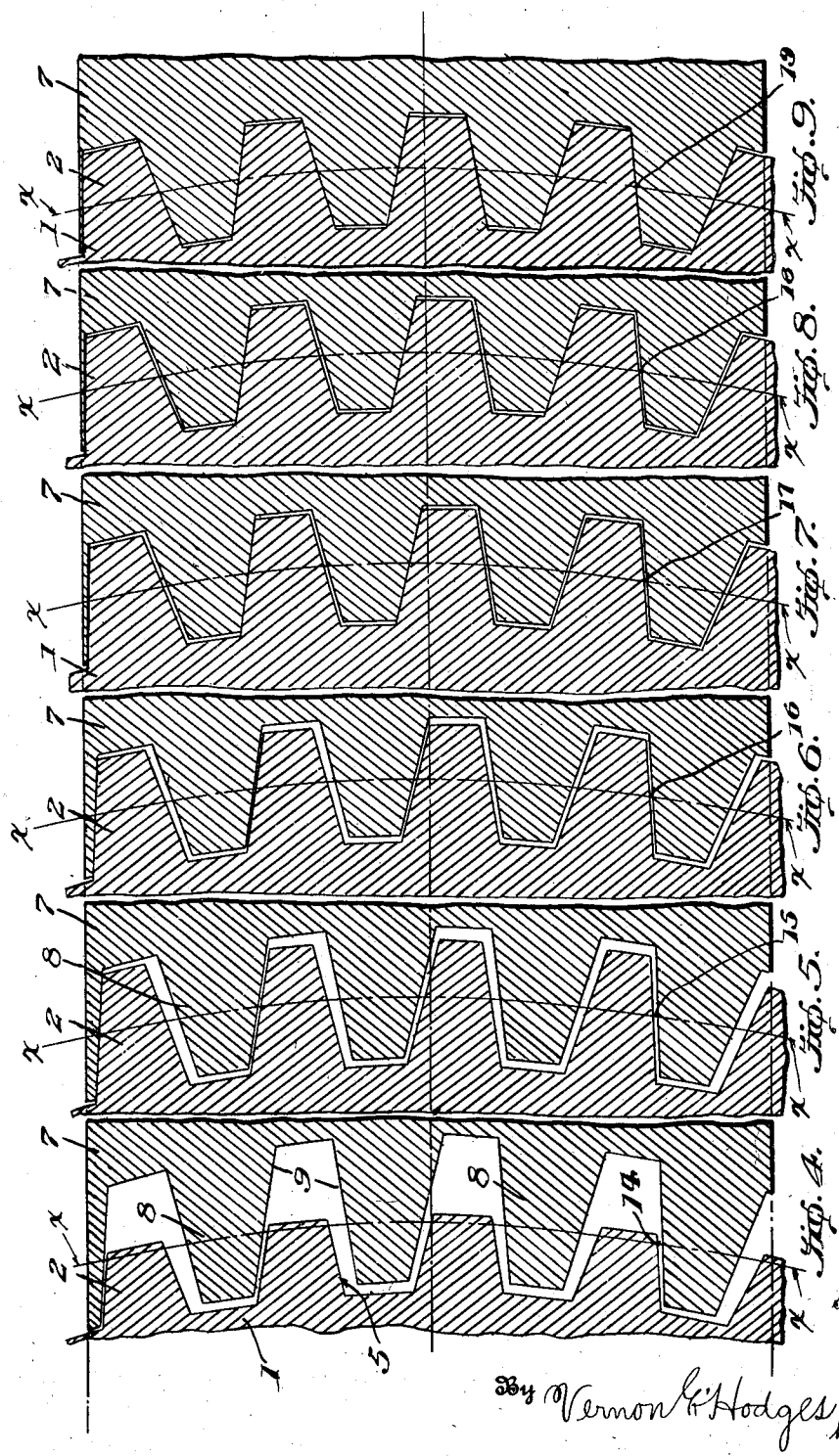
Samuel I. Cone

By Vernon C. Hodges his Attorney

Sept. 8, 1931. S. I. CONE 1,822,800

HINDLEY WORM GEAR

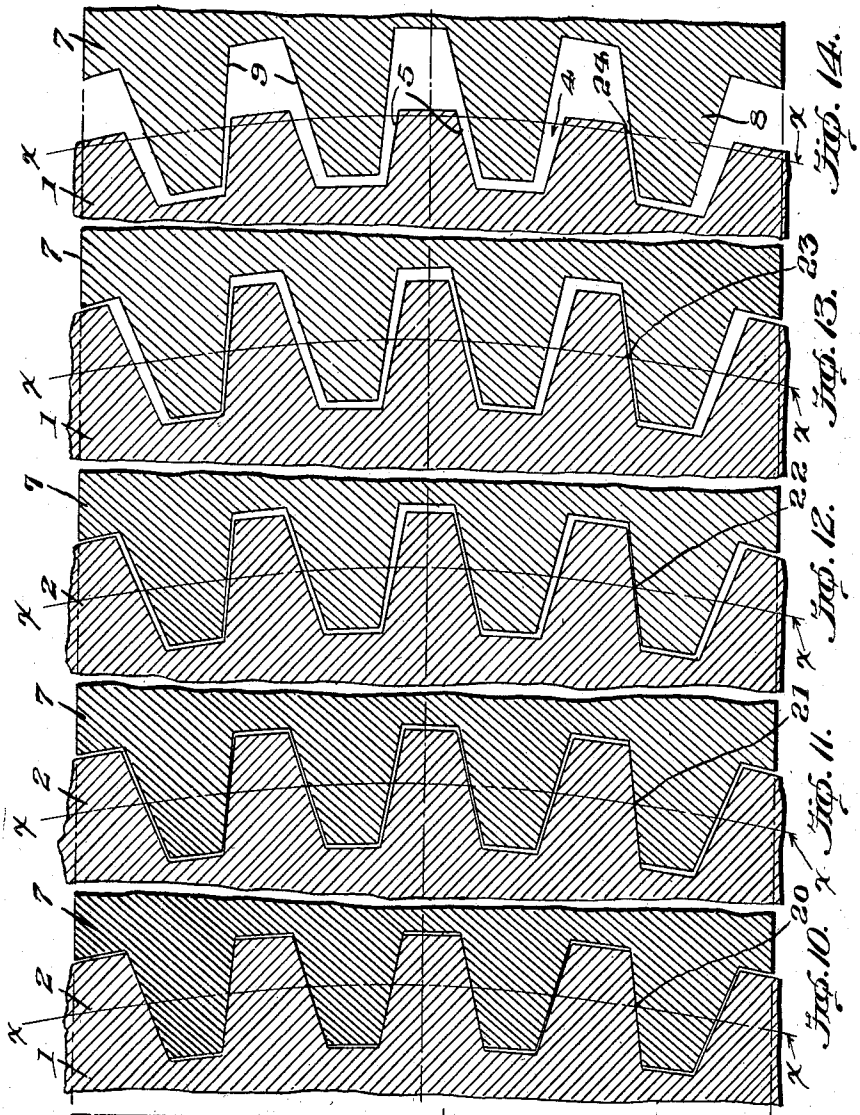
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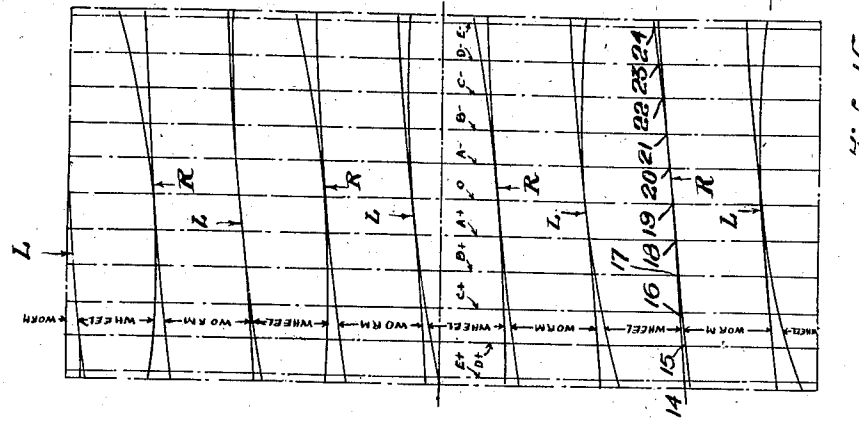


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HINDLEY WORM GEAR

Filed June 27, 1925 4 Sheets-Sheet 3





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HINDLEY WORM GEAR

Filed June 27, 1925 4 Sheets-Sheet 4

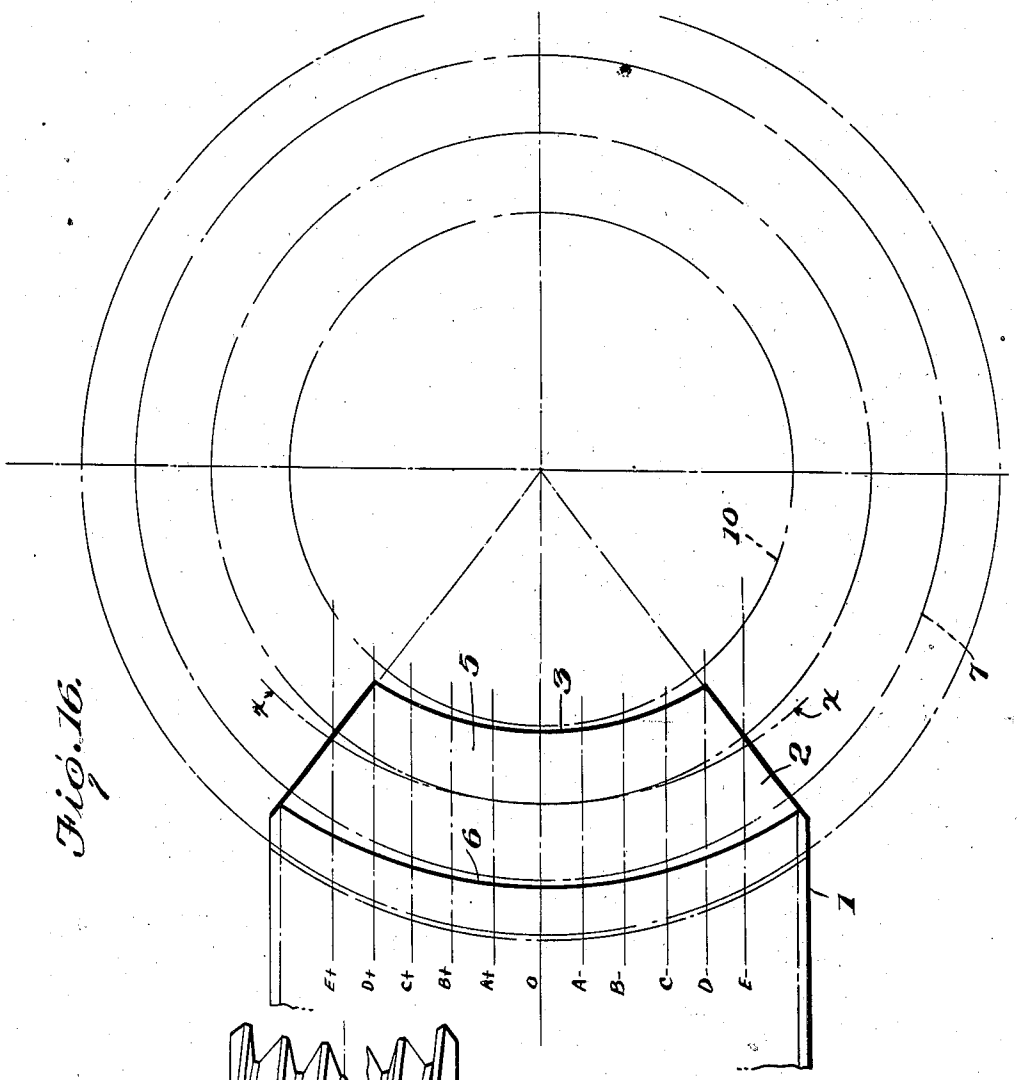


Fig. 16.

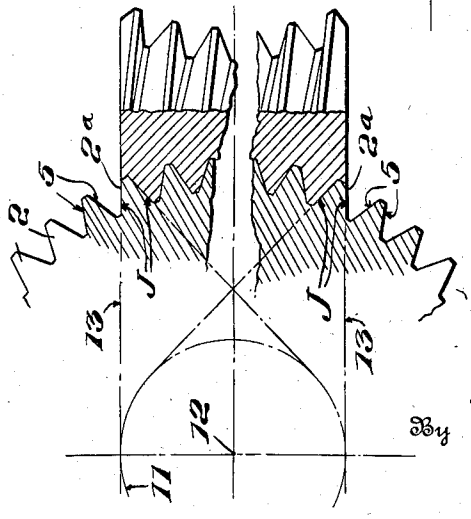


Fig. 17.

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UNITED STATES PATENT OFFICE

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HINDLEY WORM GEAR

Application filed June 27, 1925. Serial No. 40,113.

This invention relates to an improved Hindley worm gear.

Objects of the present invention are to provide a worm of the hourglass or Hindley type and a mating wheel, having thread and teeth both formed in accordance with principles of design which are of such character as to lend themselves to the application of definite co-ordinating mechanical processes which, when solely employed, result in the production of parts possessed of ideal intermeshing qualities; to provide a design of worm and wheel in which there exists a certain precision of mating between the thread and teeth throughout the length of the worm, possessing the maximum amount of surface contact and presenting when actuated a purely sliding engagement of surfaces; and to provide a worm and wheel with thread and teeth so designed in form that the application of a simple and definite cutting method will complete each element, thus rendering unnecessary such modifications as would otherwise be required to more nearly accomplish this end.

As is well known, the uses and principles of operation of the hourglass or Hindley worm are in common with those of the ordinary or straight worm, the former embodying modifications of form which increase its capacity of close intermeshing with the wheel teeth and by which it overcomes to a great extent the very natural defect existing in the use of the straight worm due to the concentration of the transmitted load. These modifications of form embraced in the hourglass type of worm result also in changing the character of the working contact between the thread and the wheel teeth which in the use of the straight worm partakes of both rolling and sliding qualities while in that of the hourglass worm a sliding quality alone exists. It is, therefore, apparent that a worm of the hourglass type and its mating wheel, a combination though only approximately formed as heretofore produced, may possess advantages over a system in which the worm is straight.

The object of the present invention is, therefore, to so provide an hourglass worm thread and its mating wheel teeth that the assembled parts will show precision of engagement when taken through the axial section and will result in the minimum departure from surface contact when taken above or below said section, the principles being simple and such that those skilled in the art may definitely apply them in producing the parts, thus eliminating the practice of "second cutting" or grinding and the resulting uncertainty of contact value.

It will be understood that in order to provide the intimate mating qualities set forth herein, it is essential during the flank finishing operation in connection with forming each member to have the cutting edges of the tools follow the natural conformity, respectively, of the thread flank of the worm and the tooth flank of the wheel in its passage through the other member. Otherwise stated, the cutting action of the tools in producing each member must conform substantially to the action of wear which would take place when the finished parts are operated in service. It will, therefore, become apparent that the time relationship and center distance between the axes of rotation must be in accordance with the actual working conditions.

The said conditions may be fulfilled by rotating a work blank and cutter about axes perpendicular to each other in the predetermined timed relation and having the said blank and cutter asume relative positions as in service, including the working center distance between the axes of rotation and then cutting the threads on the worm, or teeth on the wheel, by means of end cutting tools radiated out during the cutting operation, while maintaining a fixed distance between the center of rotation; or by edge or side cutting tools made thinner than the required tooth or thread gap and the feed required to produce the correct form and width of tooth and thread gap being accomplished by a change in the relative position of the cutter and work blank, by shifting either member angularly about its own axis while maintaining the proper timed and position relationship, including fixed distances between the axes or rotation.

It will be understood that in cutting the worm threads, that so-called fly cutters will produce the required form, regardless of the helix angle or ratio selected, and that additional cutters are employed where more rapid cutting is desired. The production of the worm wheel presents a different problem, in that whereas small helix angles and large ratios may be cut substantially correct by means of fly cutters, in the case of large helix angles and small ratios cutting edges representing the different positions of the thread flanks are required, said condition coupled with the usual requirement of more rapid cutting makes the use of a hob preferable for such work.

And this invention, therefore, provides for actual surface contact between the thread of the worm and the teeth of the wheel, which surface contact extends substantially across the width of the tooth at the entering end of the worm, gradually reducing in width as the leaving end of the worm thread is approached. This definite surface contact, which is the maximum amount that can be obtained, is brought about and produced not only by the particular method or process of generating the worm and wheel but also by the relation which exists between the teeth of the worm wheel and the maximum length of the worm. The teeth of the gear wheel are of a peculiar twisted shape in order accurately to fit and receive the thread on the worm. The length of the worm is limited to the diameter of the circle described about the center axis of the worm wheel, which circle is such that the flanks of the gear teeth taken in an axial section through the mid-plane would, if produced, be tangent thereto. Although the worm could be shorter in length than the diameter of this circle, yet, if it were made shorter, a considerable amount of the bearing surface at the outer end of the worm would be lost, since this surface bearing is greatest at the entering end of the worm. Therefore, this particular relation produces the maximum amount of surface contact which it is possible to obtain.

In the accompanying drawings:

Fig. 1 is a side elevation of my improved Hindley gear with a detail view of a portion of the worm wheel in position to intermesh therewith;

Fig. 2 is an enlarged side elevation of one portion of the thread projection on the worm;

Fig. 3 is an enlarged side elevation of a portion of the gear wheel for receiving the thread projection on the worm;

Fig. 4 is a sectional view on the lines E+—E+ of Figs. 2, 3, and 16;

Fig. 5 is a similar view on the lines D+—D+ of Figs. 2, 3, and 16;

Fig. 6 is a similar view on the lines C+—C+ of Figs. 2, 3, and 16;

Fig. 7 is a similar view on the lines B+—B+ of Figs. 2, 3, and 16;

Fig. 8 is a similar view on the lines A+—A+ of Figs. 2, 3, and 16;

Fig. 9 is a similar view on the lines O—O of Figs. 2, 3, and 16; or at the mid-plane of the worm and wheel;

Fig. 10 is a similar view on the lines A−—A− of Figs. 2, 3, and 16;

Fig. 11 is a similar view on the lines B−—B− of Figs. 2, 3, and 16;

Fig. 12 is a similar view on the lines C−—C− of Figs. 2, 3, and 16;

Fig. 13 is a similar view on the lines D−—D− of Figs. 2, 3, and 16;

Fig. 14 is a similar view on the lines E−—E— of Figs. 2, 3, and 16;

Fig. 15 is an expanded diagrammatic view of the contact between the gear teeth and the thread of the worm, taken on sectional lines x—x of Figs. 4 to 14, inclusive, and Fig. 16.

Fig. 16 is a diagrammatic view on the plane of the gear axis showing the relation between the worm and worm wheel when intermeshed;

Fig. 17 is a side elevation partly in section of the worm and wheel intermeshed.

It is universally admitted that the ordinary type of Hindley worm gear, having several teeth of the wheel in mesh with the worm thread, though with only a line contact, is greatly superior to the straight type of worm gear in which the whole load is carried on one or two teeth and with only a point contact at that, due to the form of the teeth and the rolling action between the surfaces. This straight worm gear necessarily has a high concentrated unit stress on the contact points, which in the ordinary Hindley gear is distributed over the line contacts of the several teeth in mesh.

This invention provides an improved Hindley gear in which this load is further distributed over an equal number of surfaces, which extend not only across the entire depth of all of the teeth in mesh but also substantially across the width of the tooth at the entering end of the worm, gradually reducing in width as the leaving end of the worm is approached. The surface bearings or contacts of this improved Hindley gear are as superior to the contacts of the ordinary Hindley gear as the latter are to the contacts of the straight worm gear. It has been established that this improved Hindley gear gives the maximum surface contact between the thread of the worm and the teeth of the wheel.

Referring to Figs. 1 and 3, of the drawings, the numeral 1 indicates a gear wheel having the teeth 2 formed on the periphery thereof. The outer ends of the teeth 2 are concaved as at 3 sufficiently as shown in Figs. 1, 3, and 16, to receive and properly fit the intermeshing worm gear. The space 4 between the flanks

5 of the teeth 2 is also concaved as at 6 to properly receive and fit over corresponding and intermeshing portions of the worm thread. As will appear in the developments Figs. 3 and 4, the flanks of the teeth are reversely curved which define thread gaps with reverse flares. In short, a top view of the teeth with flanks so formed gives the impression of the letter **S**.

The worm 7 is provided with a thread 8 as shown in Figs. 1 and 2 adapted to be received and fit closely within the recessed portion 6 of said wheel, the sides 9 of said thread 8 being adapted to wipe across the flanks 5 of the teeth 2. The thread 8 on the worm 7 is shown as having five turns about the core 10 of said worm and, as such, would mesh with five of the teeth on the worm wheel 1. The thread 8 is adapted to engage teeth on the worm wheel 1 throughout the length of the worm, and the length of the worm and the corresponding number of teeth to be engaged may be varied as desired.

In Fig. 17, the flanks 5 of the teeth 2 at the axial section are straight and, if projected through the wheel, pass within equal distances from its center 12 thus becoming tangent to a circle 11 concentric with the center 12. It will be seen that the lines 13 drawn tangent to this circle and parallel to each other when projected across the intermeshing worm will establish its maximum threaded or working length. If this length be exceeded the thread and teeth will become locked, thus preventing the separation of the parts. The working length of the worm may be less than the diameter of the said concentric circle but the maximum benefits derived from the use of the system are possible only when the limit of length is used.

This maximum surface contact is revealed by an examination of Fig. 15 in which the contacts between the worm thread and the teeth are illustrated, the paired lines of the working faces being shown converging, uniting, and diverging respectively. The contacts are thus presented in their most unfavorable aspect since the engagements shown are active across the whole tooth depth. In Figs. 4 to 14 inclusive are shown the contact or space values at the various levels as O, A+, A−, etc. Examination of these referring also to Fig. 15 will show the values in both directions as 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24. The worm thread, as shown, is left handed and when operated to left will create pressure between the alternating pairs of contacting surface lines as indicated by the arrows L and in the direction shown. It will be noted that the first pair of lines L representing the entering end of the thread are almost completely coincident while the coincidence of the succeeding pairs L_4 is reduced in a uniform order, the final pair representing barely more than line contact of the thread and tooth. If the drive be reversed in direction the engaging contact will be represented by the pairs of lines marked by and in the direction of the arrows R, which will also represent a reversal of the order of bearing values. Thus, it is shown that the entering end of the worm thread, whichever the direction of rotation, will possess the greatest surface bearing value, hence the importance of the maximum permissible working length for the worm. The bearing value fluctuates to some degree near the entering end of the worm thread due to the position in rotation of the latter, the minimum occurring immediately before the end of the thread engages the tooth and the maximum immediately after.

Referring to Fig. 17, it will be seen that the concentric circle 11 subtends the tooth angle in the axial section, its diameter thus being determined by said angle, and since the working length of the worm equals this diameter it follows that the worm length is controlled by the tooth angle.

The sides of the teeth being coincident throughout the axial section with the straight side lines of the worm thread it is evident that the correct thread form may be generated on the rotating worm by moving these lines in their fixed relationship to each other, or a tool with cutting edges corresponding to these lines, about an axis coincident with the axis of the wheel and in the axial section, the desired ratio of movements of parts being observed.

Since the side lines of the teeth must coincide with those of the worm thread in the axial section, it follows that the principles of formation for both must possess something in common.

Therefore, if the wheel in Fig. 17 be rotated about its axis the sides of its teeth in one direction will each in its turn become coincident with the line 13 at one end of the worm, while those of the other sides of the teeth will in turn likewise coincide with the line 13 at the other end of the worm. Since these lines 13 are parallel to each other and at right angles to the worm axis, it follows that by rotating the generating lines $2a$, or tool edges, about an axis coincident with the worm axis in the planes of the lines 13 the proper tooth twist will be generated on the rotating wheel, the desired ratio of movements of parts being observed.

As the generating lines would both in practice very infrequently pass through the axial section at the same time, the view is broken and adjusted to show both.

While in the combination used in this description the worm has only one thread, the utility of the principle is obviously not so limited, the number of worm threads and wheel teeth being such as required.

The pitch of the worm and worm wheel is exactly the same, and every tooth on the

wheel that is in mesh with the worm will have a surface contact with the worm thread and will bear its proportionate part of the total load. This uniformity of contact reduces the unit stress and permits a uniform flow of oil to be carried through the teeth, reducing friction, preventing heating, and decreasing wear, thus lengthening the life of the gear. As a result of the worm and wheel being of exactly the same pitch and in uniform contact, it is evident that the worm and wheel cannot wear out of pitch, remaining in pitch in both directions until worn out, regardless of the amount of wear or backlash.

For renewing either the worm or wheel of this improved Hindley gear, it is only necessary to know the center distance, pitch, etc. to make either a worm or a wheel which will fit the corresponding wheel or worm that does not need renewing. With the ordinary Hindley gear, both the worm and wheel must be renewed in case either one breaks down or wears out, and needs replacement, each wheel fitting on to the worm with which it was made, and vice versa, and will fit no other part made of different type. As the worm and wheel of my improved Hindley gear are not ground together and are not dependent on each other for accuracy of fit, it is not necessary to renew both when only one is worn out.

Thus, it will be seen that actual surface contact is had between the thread of the worm and teeth of the wheel of my improved Hindley gear, which distributes the load over the maximum surface of each of the teeth in mesh, giving the maximum surface contact between the teeth and thread as opposed to the nearer line contact which is the most that it is possible to obtain with the ordinary Hindley gear.

I claim:

1. The combination of a worm of the hourglass type having threads generated about an axis coincident with that of the mating wheel and in the axial section of the worm; and a mating wheel having the sides of its teeth generated by lines rotating about the worm axis in planes at right angles to the worm axis, said planes being two in number and each an equal distance from the plane of the wheel axis and in opposing directions therefrom, the same producing surface contact substantially as described.

2. Gearing comprising worm and worm wheel elements of the hourglass type, the thread of the worm being of constant axial pitch and of length not exceeding the diameter of a circle described about the center axis of the mating wheel element and such that the flanks of the thread if projected in axial section would be tangent to it, the teeth having reversely curved flanks whereby when the worm and worm wheel are intermeshed and in relative motion there is afforded more than point or line contact.

3. Gearing comprising worm and worm wheel elements of the hourglass type, the thread of the worm being of constant axial pitch and of length not exceeding the diameter of a base circle described about the center axis of the mating wheel element and such that the flanks of the thread if projected in axial section would be tangent to it, the teeth having reversely curved flanks defining thread accommodating spaces with reverse flares.

4. Gearing comprising worm and worm wheel elements of the hourglass type, the thread of the worm being of constant axial pitch and of length not exceeding the diameter of a base circle described about the center axis of the mating wheel element and such that the flanks of the thread if projected in axial section would be tangent to it, the teeth having reversely curved flanks defining thread accommodating spaces with reverse flares, for the purpose and with the result of establishing substantial surface contact which is at its maximum at the entering end and declines towards the leaving end of the worm thread whether the drive be forward or reverse.

5. A gear of the Hindley type, including a worm, and a worm wheel whose flanks when projected in the midplane become tangent to a circle circumscribed about the axis of the wheel, said flanks having warped surfaces, the worm substantially equaling in length the diameter of said circle and having a constant axial pitch.

6. The combination of a worm of the hourglass type, having threads formed about an axis coincident with that of the mating wheel and in the axial section of the worm to provide for constant axial pitch, and a mating wheel having teeth generated in conformity with the worm thread flanks and whereof the flanks present warped surfaces formed on reversed curves.

7. A system of gearing comprising, in combination, a worm wheel having teeth, the flanks of which are sinuously warped, and a worm generated to intermesh therewith with substantial surface contact.

In testimony whereof I affix my signature.

SAMUEL I. CONE.