Aug. 20, 1935. N. TRBOJEVICH 2,011,956

METHOD OF GRINDING WORMS AND SCREWS

Filed July 7, 1930 3 Sheets-Sheet 1

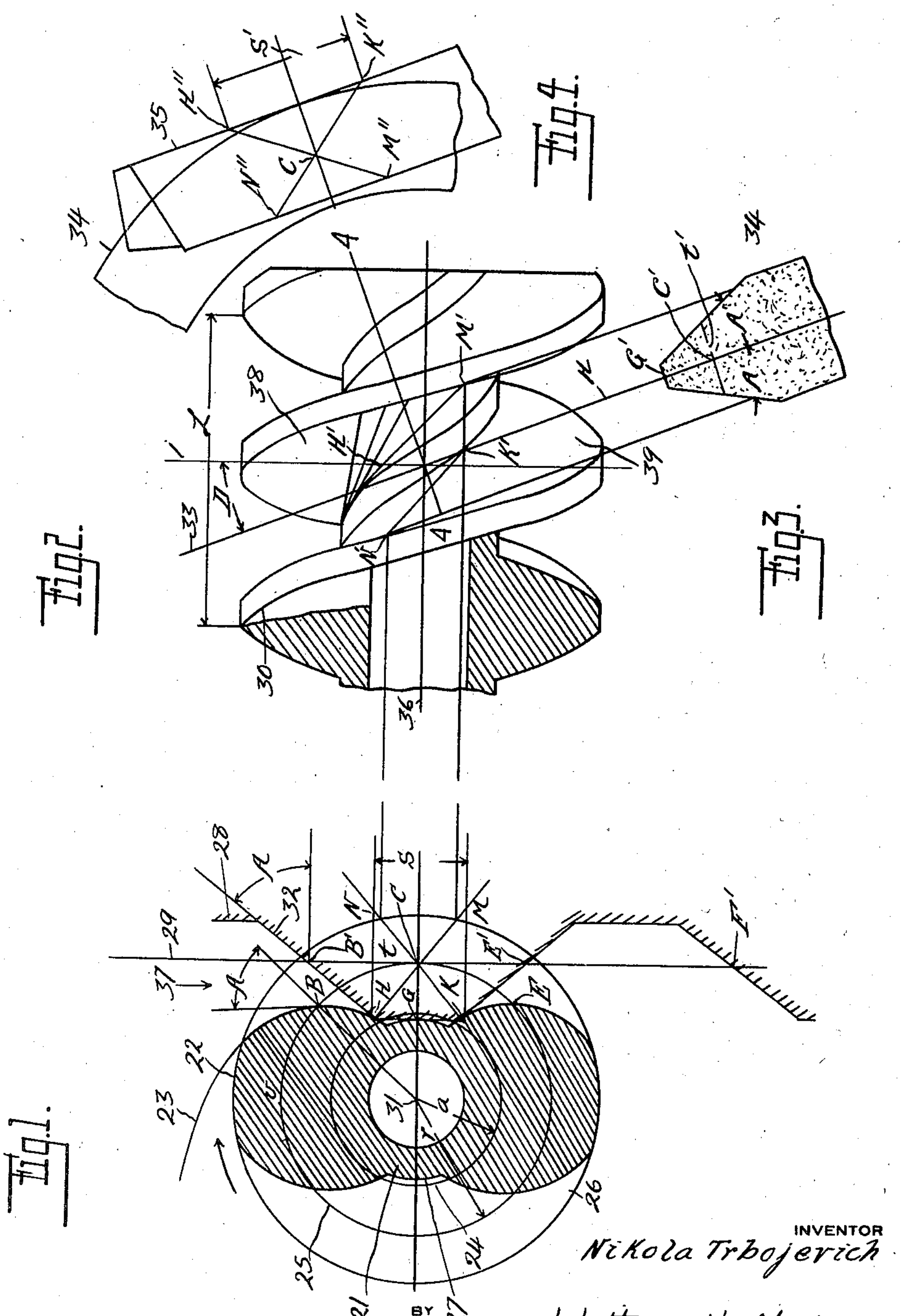

Fig. 1. Fig. 2. Fig. 3. Fig. 4.

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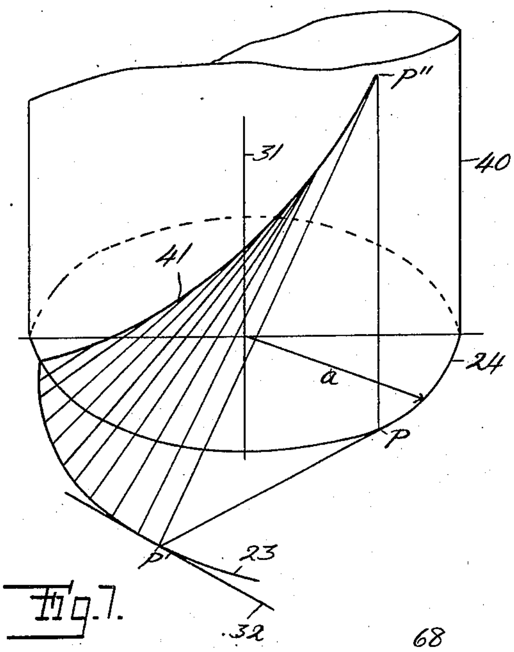


Fig. 7.

Fig. 5.

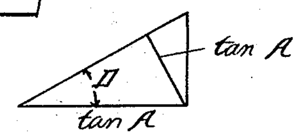
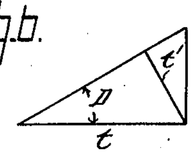


Fig. 6.



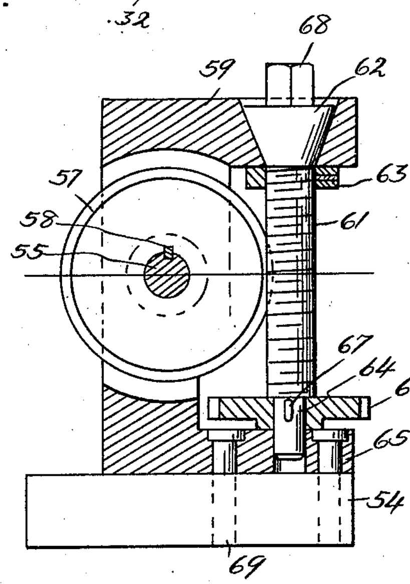


Fig. 9.

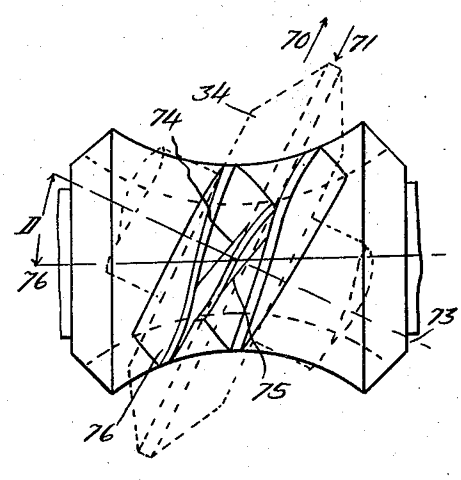


Fig. 10.

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3 Sheets-Sheet 3

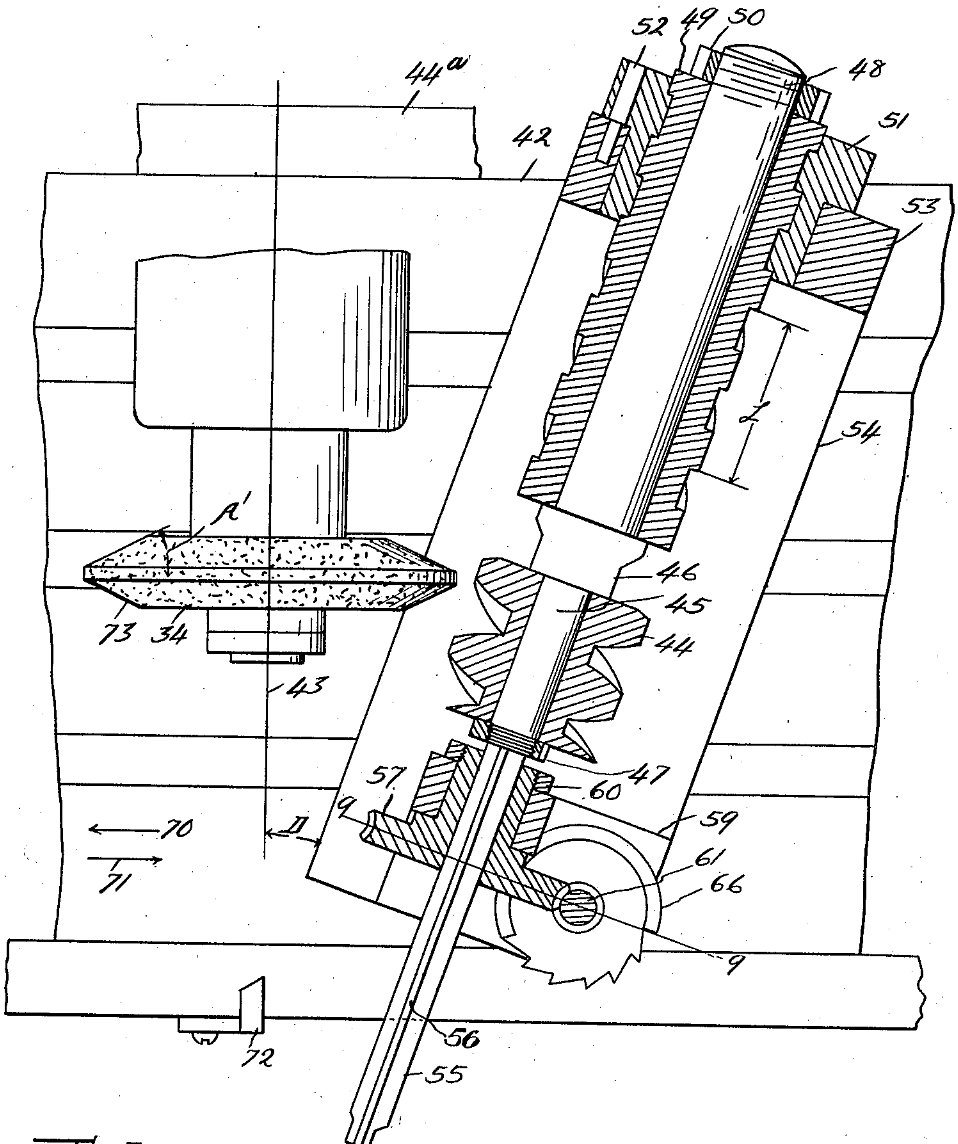

Fig. 8.

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METHOD OF GRINDING WORMS AND SCREWS

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7 Claims. (Cl. 51—278)

The invention relates to a novel method of grinding worms and screws.

Heretofore such worms were ground by means of a disk wheel which was positioned in its plane at an angle relative to the worm axis and the work was rotated and translated relative to the wheel in a succession of rapid "passes". After each "pass" the machine would stop and the work (or the wheel) would be returned to its initial position and another pass would be taken. In order to prevent the burning or cracking of the work the passes had to be taken at a considerable rate of speed, from 15 to 70 ft. per minute, thus giving passes of a very short duration, especially so in the worms that were comparatively short and had a steep helix angle, as in automobile axle worms, for instance.

I have found three fundamental disadvantages existing in the above described conventional method and have succeeded in eliminating all three of them by improving the method of grinding as hereinafter shown. The first disadvantage, the short duration of individual operations or passes, I have already mentioned. The second disadvantage is that the form as ground in the worm thread depends not only upon the exact shape to which the wheel is dressed but also upon the diameter of the wheel, the so-called helical interference. This is a considerable source of trouble because the wheel is reduced in diameter each time it is dressed, thus producing slightly different work each time. The third disadvantage is that the wheel engages the work with a line contact thus preventing the ground off particles from leaving the place of contact instantaneously and causing overheating, clogging and scratching.

In my improved method I position the wheel in the same fashion as before, but I oscillate the same in its plane tangentially and transversely of the worm. The oscillations are selected not haphazardly, but according to a prearranged plan, namely, the length of stroke is such that the wheel will clear the area of contact of the work with an imaginary prism or rack tooth at each end of the stroke and the rate of reciprocation is such as to produce the required surface speed of from 15 to 70 ft. per minute. By this means I first change the nature of wheel contact completely by going from a line to point contact; second, the produced form is now independent of the wheel diameter and third, the duration of each "pass" may now be made as long as desired and the entire stock may be removed in one pass only instead of tens and hundreds of passes as formerly required.

The objects of this invention are to prevent overheating in grinding, to produce more accurate work, to save labor and wear and tear upon the machine and to reduce the expense for emery wheels.

In the drawings

Figure 1 is the transverse section of the worm taken in the plane 1—1 of Figure 2;

Figure 2 is the side view of the worm diagrammatically represented;

Figure 3 is the cross section of a grinder capable of generating the worm shown in Figures 1 and 2;

Figure 4 is a diagram showing the grinder and the imaginary prism mating with the worm in plane 4—4 of Figure 2;

Figures 5 and 6 are diagrams explanatory of the Equations 4 and 5;

Figure 7 is a perspective view of an involute helicoid;

Figure 8 is the plan view of my improved worm grinder;

Figure 9 is the section 9—9 of Figure 8 showing the feed mechanism employed in this machine;

Figure 10 is a diagrammatic view of a globoid worm being ground on this principle.

The principle upon which this invention is based will now be explained. In Figure 1 the transverse cross section or lamina of a worm which it is proposed to generate is shown. Said lamina 21 possesses two equispaced lobes 22 (thus indicating a double threaded worm), each lobe being bounded on its two sides by two similar transverse tooth curves 23 which are preferably involutes developed from the base circle 24, but they also may be any other curves such as Archimedean and other spirals without affecting this broad principle.

A pitch circle 25 is now selected or established and the tooth curves 23 are fixed in their relative positions by assuming a thickness of tooth u measured along the arc of the said pitch circle, while the active or contact surface of the said curves will extend from the outside circle 26 to within a short distance from the root circle 27, thus providing a clearance space at the bottoms of the worm teeth.

In order to generate a worm from the said lamina 21 we rotate and translate the same at a fixed ratio about the axis 31 perpendicular to and concentric with the lamina, thus producing an infinite number of helixes 30 all having the same lead L, Figure 2. The lamina 21 may be considered as a spur gear element and thus it will correctly mesh with a rack 28 having a pitch line 29 tangent to the pitch circle at the point C, a pressure angle A equal to the pressure angle of the tooth curve 23 at the point B where the said curve intersects the pitch circle 25, and a tooth flank 32 conjugate to the said curve 23. The flank 32 will be a straight line if the curve 23 is an involute and will be a curve in all other cases.

It is now evident that inasmuch as the lamina 21 is rotated and propagated uniformly, the rack 28 in order to remain in mesh with the said lamina will have to be moved in two mutually perpendicular directions, i. e. along its pitch line 29 and the worm axis 31. Thus, the rack 28 will describe a prism having an axis coincident with the line 33, Figure 2, and an angle of inclination D corresponding to the helical angle of the worm. If we now denote the width of space BE of the lamina with t, measured along the arc the thickness of the rack tooth B'E' will also be equal to t and the pitch of the rack $p=B'F'$ will be equal to

$$p=u+t=\frac{2r\pi}{n} \qquad (1)$$

where r is the pitch radius and n the number of teeth or lobes in the lamina.

It stands further that

$$\cos A=\frac{a}{r} \qquad (2)$$

where a is the base radius, and

$$\tan D=\frac{L}{2r\pi} \qquad (3)$$

To determine the cross section of the grinder 34, Figure 3 we must know its thickness t' and its pressure angle A'. From the triangles Figures 5 and 6, we have

$$\tan A'=\tan A \sin D \qquad (4)$$

$$t'=t \sin D \qquad (5)$$

and

$$G'C'=GC, \text{ Fig. 1}$$

Now, the object of this invention is, first, to find the prism meshing with the worm to be ground, second, to mechanically reproduce the said prism by means of an oscillating grinder, third, to determine the necessary amplitude or length of stroke of the said grinder and fourth, to rotate and translate the worm in order to finish both sides of the thread from end to end in one cut.

The next step will be to determine the lines of contact of the prism 35, Figure 4 with the worm threads. In order to do this we begin with the Figure 1 in which the two lines of action HCM and KCN are first determined. These two lines will be both straight and tangent to the base circle in the involute system, will be certain curves in any other system and will cross each other at the pitch point C in all systems.

When the lamina 21 is rotated in the direction of the arrow 36 the rack will translate in unison in the direction of the arrow 37 and the points of tangency will move along the two pressure lines HCM and KCN, thus requiring the projected length of stroke S to completely finish the curves 23 from top to bottom. Therefore, if we project the said pressure lines upon the worm thread surface in Figure 2 we obtain the two skew lines N'K' and H'M' respectively, said lines being the locus of the simultaneous contact of the worm thread with the prism 35 at any one instant.

Although the thread surfaces 38 and 39 are warped and curved it is readily proved that in involute system both lines of contact N'K' and H'M' respectively are straight lines and are oppositely inclined relative to the plane of paper, Figure 2 without intersecting each other. That these lines are straight follows from Figure 7 which diagrammatically represents another well known method of generating an involute helicoid. A right angle triangle PP'P'' rolls upon the base cylinder 40 in such a manner that its adjacent side PP' rolls upon the base circle 24 and its hypothenuse P'P'' rolls upon the base helix 41 thereby describing with the apex P' an involute 23 in the plane of the said base circle. The helicoidal surface is, therefore, composed of straight lines P'P'' which are at each instant perpendicular to the tangent 32 to the involute 23, said tangent being identical with the rack tooth flank 32 as shown in Figure 1. Due to the fact that the developed length of the generator P'P'' is exactly equal to the arc length of the helix 41 it follows from the theory of such surfaces (developables) that the plane comprising the perpendicular lines 32 and P'P'' is tangent to the surface and the line of tangency is along the generator P'P''.

It will be of interest to note how I increase the productive ability of this type of the machine up to its theoretical maximum. This maximum will be attained when the projected length of the stroke S, Figure 1 will be the minimum. Therefore, I select the pitch circle 25 in such a relation to the depth of thread, that the projections of the points HNKM will produce the minimum amplitude as measured in the direction of the rack pitch line 29. This will happen when the pitch line is located at a certain point not far removed from the middle of the working depth.

To summarize the results of this investigation in the theory, we are now enabled to select the pitch line properly i. e. such that the length of stroke will be the minimum and the two opposite sides of the thread will be simultaneously generated; we also may compute the length of the stroke S', Figure 4 the normal thickness t' and the normal pressure angle A' of the wheel.

Figure 8 shows the plan view of a simple and yet operative machine for grinding worms in accordance with my invention. This machine may be constructed from an ordinary surface grinding machine and it will be found to be reasonably accurate and automatic (during one complete pass) in its operation.

The work table 42 of the machine reciprocates in a direction at right angles to the wheel axis 43 in the bed 44a of the machine and the number, speed and length of strokes are adjusted in the same manner as in any other surface grinder. The grinding wheel 34 may be of any desired diameter and should be rapidly rotated to have a peripheral speed of about five to six thousand feet per minute in order to grind hardened steel. The wheel contour is V-shaped and is dressed to the exact dimensions as was shown in Figure 3. The worm to be ground 44 is mounted upon the arbor 45. It abuts the shoulder 46 with its one end and is kept tightly clamped in position by means of a nut 47 at its other end. The rear end of the arbor 45 is formed in a mandrel 48 and carries a master screw 49 which is tightly clamped upon the said mandrel by means of the nut 50. The diameter, the form of thread and the number of threads in the master 49 may be arbitrarily selected; however, it is necessary that its lead be exactly the same as that of the worm 44 and its hand also must be the same.

The master 49 snugly fits into the nut 51 which is preferably made of cast iron lined with babbitt and is clamped by means of screw 52 in a bore situated in the upper part of the vertical shank 53 of the base plate 54.

The front end of the arbor 45 is formed into a sliding spindle 55 and is provided with one or more longitudinal keys 56. The feed worm gear 57 is of the self-locking (single thread) type, it is keyed to the spindle 55 by means of the key 58 (Figure 9), and is rotatably housed in the corresponding bore of the bracket 59, being held there in position by means of the thrust collar 60. The feed screw 61 (Figure 9) is formed in a taper journal 62 at its upper end where it rotatably fits in the corresponding taper bearing of the bracket 59, and is held in position by means of the thrust collar 63. The said screw 61 snugly fits into the teeth of the worm gear 57 with little or no backlash and is pivoted by means of the pivot 64 in the base 65 of the bracket 59. A ratchet 66 is keyed by means of a key 67 to the said feed screw and serves to operate the same at suitable intervals. The said screw is also operable by hand by means of the square shank 68, formed at its upper end. The bracket 59 is securely bolted to the base plate 54 by means of bolts 69.

The operation of this machine will now be explained. The axis of the worm 44 is inclined at the helix angle D relative to the axis 43 of the wheel and the worm is reciprocated in the directions of the arrows 70 and 71, perpendicular to the said wheel axis. Thus, the wheel 34 describes a prism or a rack tooth tangential to the worm thread in the space. Upon each stroke of the table 42 two lines N'K' and H'M' respectively (see Figure 2) will be ground in the worm thread and if we now slowly rotate and translate the worm along its axis, upon the next stroke another two lines will be generated adjacent to the above mentioned lines N'K' and H'M' and also lying in the worm thread.

In the practical example shown in Figure 8, I have 100 teeth in the feed worm gear and 16 teeth in the ratchet, thus obtaining a ratio of 1600 to 1 giving a spacing of generated lines in the finished worm thread about four thousandths of an inch apart for a length of helix of 6½ inches. By rotating the feed worm gear 57 by means of the screw 61, the master screw 49 will rotate and also advance along its axis in the nut 51, thus carrying the worm to be ground 44 in the required and precise helical path. The ratchet 66 will engage the adjustable stop 72 once during each alternate stroke in the direction of the arrow 70 in this design, thus causing the ratchet 66 to rotate through an angle corresponding to one tooth and feed the worm the above mentioned four thousandths of an inch.

The ratchet feed mechanism shown in Figures 8 and 9 is only a modification or a design and it will be understood that this apparatus will properly work also in the case when the worm 44 is rotated continuously, e. g. by a train of gears from an outside source instead of periodically as by the ratchet. It will also be understood that instead of reciprocating the worm in the direction of the arrows 70 and 71 we may reciprocate the wheel 34 in the same direction without affecting the principle. The contours 73 of the grinder will be straight lines to generate worms which are involute in their transverse section, but will be curved for all other types of worms as already mentioned.

In ordinary work, the worm 44 is first roughed out in soft, hardened, and ground only in order to remove a very thin film of metal, usually less than about ten thousandths of an inch thick; however, in grinding high speed steel taps from the solid steel, the whole depth of thread may be taken in one cut in this method. This ability of removing comparatively large amounts of stock in one "pass", I consider as the greatest advantage of this method and this advantage is not shared by any other known method of worm or screw grinding.

Globoid worms may also be ground by this method. As is diagrammatically shown in Figure 10 the globoid worm 73 is of such a form that it will contact with a prism along two oppositely situated lines 74 and 75 in its thread surface 76. The wheel 34 reciprocates along the arrows 70 and 71 while the worm 73 slowly rotates about its axis 76 and is translated longitudinally in a circle, i. e. it is translated in a globoid helix instead of in a cylindrical or ordinary helix as for common worms. Thus both sides of the worm thread may be ground in one pass from end to end.

When the worm, straight or globoid, is multiple threaded, each thread is ground in a separate operation providing one grinding wheel only is used. In Figure 8 the worm 44 is double threaded and after grinding one thread we disengage the nut 47 and index the work in order to be able to grind the other thread without disturbing the wheel 34 in its position.

What I claim as my invention is:

1. A method of grinding worms which consists in forming a disk grinder to a profile capable of touching an imaginary prism element along a line, said prism in turn being capable of touching the helical surface to be ground along another line, in positioning the cutting plane of the grinder to coincide with the axis of the said prism, in oscillating the said grinder along the said prism axis and in the plane of the grinder in a direction transverse and tangential relative to the root cylinder of the work thereby reproducing the prism and in translating the worm along its axis in a helix until the thread is finished from end to end in the form of a series of generated lines.

2. A method of grinding a helical thread consisting in forming a disk grinder in its axial plane to a profile coinciding with the normal section of an imaginary prism member which member is capable of touching the worm thread surface along two lines, one line on each side of the thread, in reciprocating the said grinder parallel to the axis of the said prism and tangentially of the root cylinder of the work in a stroke exceeding in length the projected theoretical length of contact and in imparting to the worm a slow helical translation along the axis, thereby finishing two worm thread surfaces from end to end in the form of a series of generated lines.

3. A method of grinding worms, screws and the like in which the grinding wheel is positioned in a direction tangential of the worm thread and transverse relative to the axis of worm, in which the worm is slowly translated relative to the wheel in a predetermined helical path, in which the wheel is oscillated in its plane and in a direction tangential of the root cylinder of the work, in which the rate of oscillation of the grinder is of a sufficient rapidity to provide an adequate surface speed relative to

the work to prevent burning and in which the length of the stroke is selected to be in excess of the length of engagement of the worm thread with an imaginary prism member which the oscillating grinder represents, thereby making it possible to remove by grinding comparatively large amounts of stock in one passage of the worm in its helical path past the grinder.

4. A method of generating helical thread surfaces having a plurality of thread convolutions disposed about an axis in which a disk cutter is formed to correspond in form to the normal section of a rack tooth capable of meshing with the said worm, in which the cutter is reciprocated in the direction of the rack tooth axis tangentially of the root cylinder of the work and transversely of the said worm axis and in which the worm is slowly translated in a helical path past the cutter to finish the thread from end to end in a series of generated lines, thereby eliminating the effects of the helical interference and enabling the operator to produce an identical tooth form in the worm by using a cutter of a predetermined profile but entirely disregarding the diameter of the said cutter.

5. A method of grinding worms whose threads are wound along a circular helix and have involute cross contours as measured in the plane perpendicular to the worm axis in which a disk grinder is formed to a double conical shape, each cone angle corresponding to the normal pressure angle of the worm to be ground, and having a thickness of disk as measured over the two cones corresponding to the normal width of space of the said worm, in which the grinder is positioned tangentially of the worm thread at an angle equal to the helix angle of the worm, in which the worm is given a relative rotation and axial translation corresponding to a predetermined helix and in which the grinder is reciprocated in its plane tangent to the root cylinder of the worm, thereby generating two oppositely inclined straight lines upon each stroke of the wheel, one line in each side of the thread.

6. A method of grinding worm threads comprising imparting a helicoidal translation to the work along its axis and rapidly oscillating the grinder in its plane of rotation in a direction tangent to the root cylinder of the work relative to the work.

7. A method of grinding worms which consists in slowly feeding the work relative to a rotary grinder in a helical path along the axis of the work and in relatively rapidly oscillating the grinder in its plane of rotation in a straight line path in a transverse direction to the work axis and tangent to the root cylinder of the work, thus constantly shifting the point of momentary engagement whereby the heat is effectively dissipated from the work and grinder.

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