O. G. SIMMONS.

GENERATION OF CONVOLUTE LINES IN HOBBING CUTTERS AND THE LIKE.

APPLICATION FILED APR. 10, 1918.

1,426,680. Patented Aug. 22, 1922.

4 SHEETS—SHEET 1.

Fig. 1.

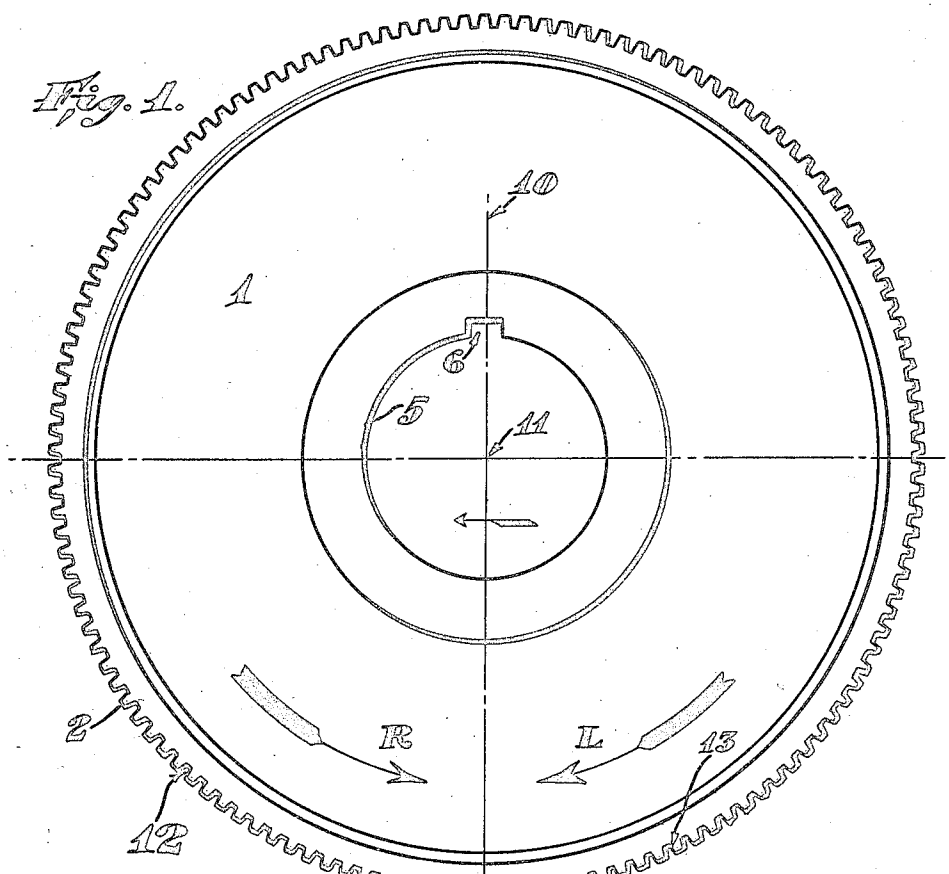
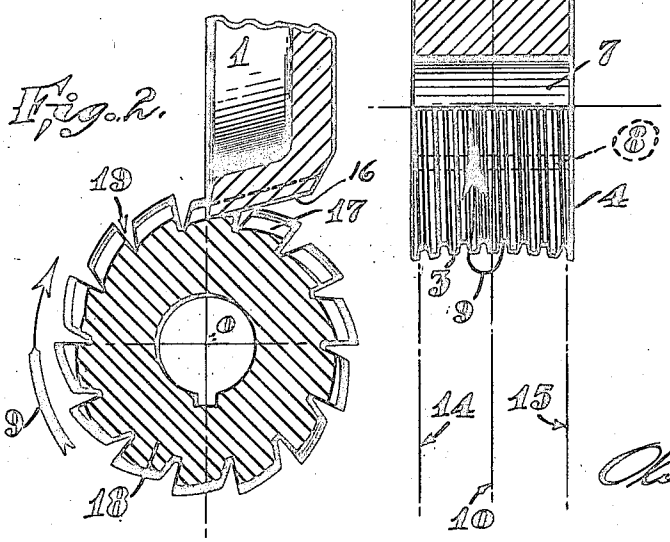


Fig. 2.



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Fig. 3.

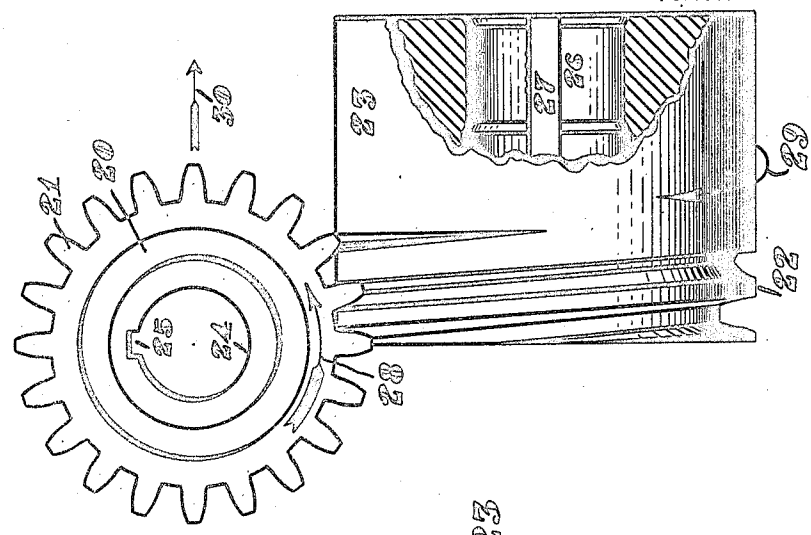


Fig. 4.

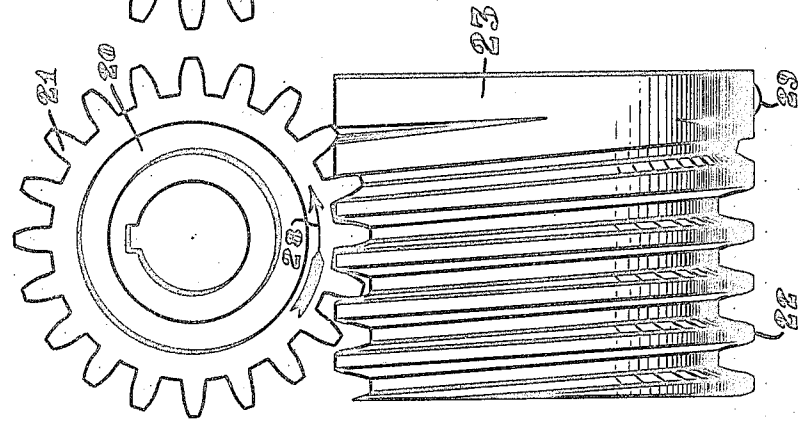
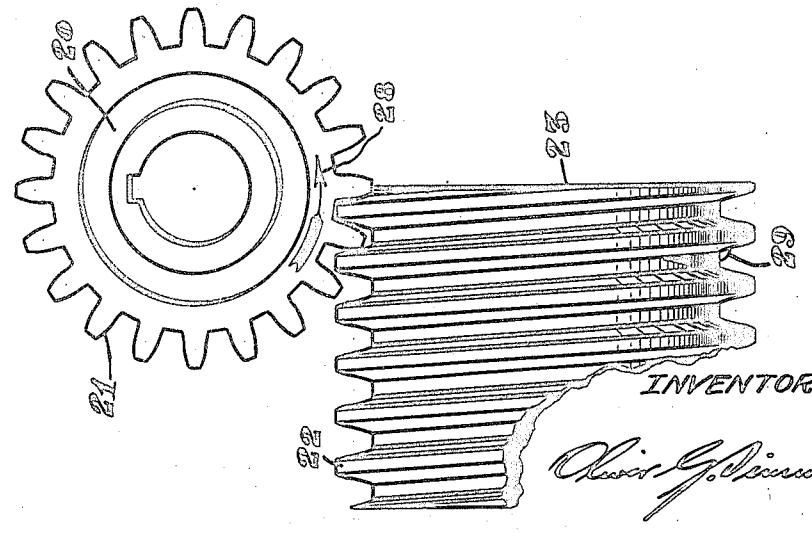


Fig. 5.



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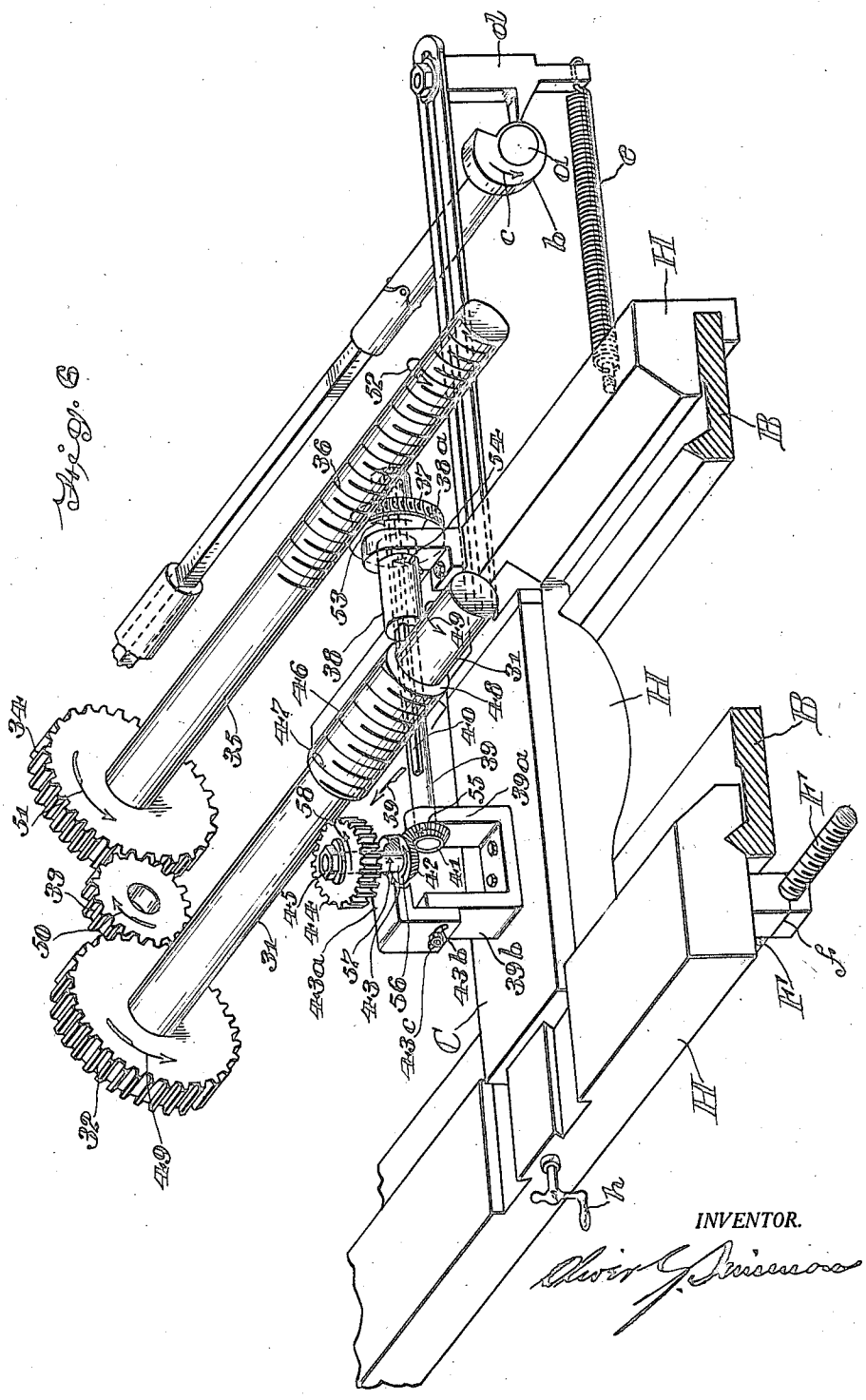
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4 SHEETS—SHEET 4.

Fig. 7.

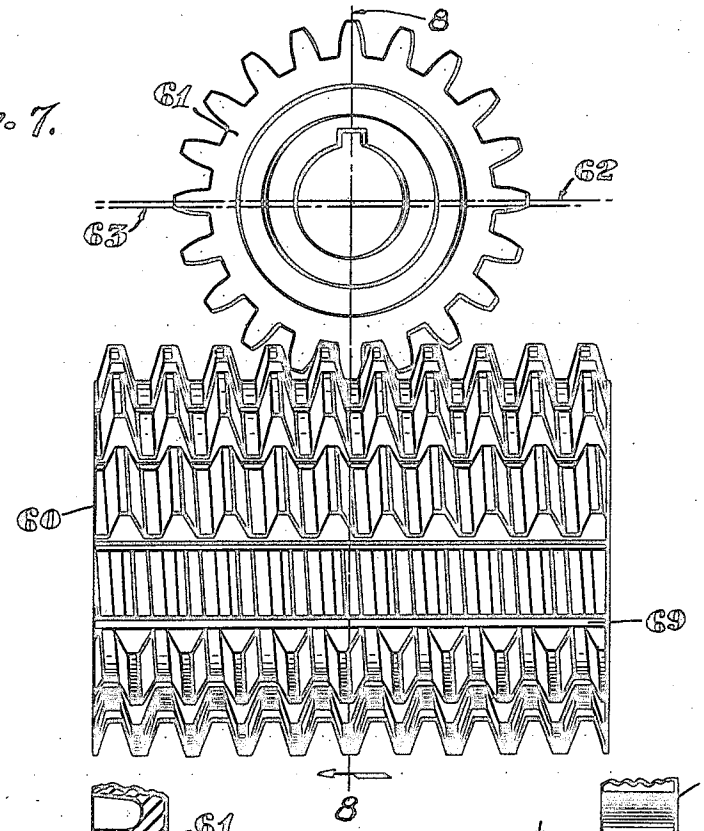


Fig. 8.

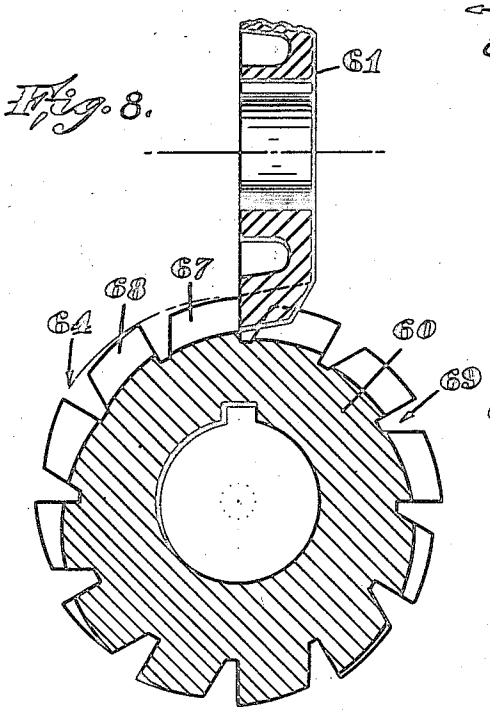
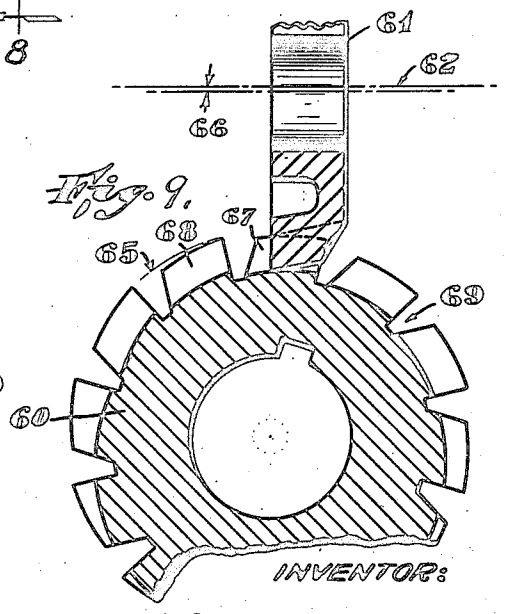


Fig. 9.



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Oscar G. Simmons.

UNITED STATES PATENT OFFICE.

OLIVER G. SIMMONS, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR TO SIMMONS METHOD-HOB COMPANY, OF PHILADELPHIA, PENNSYLVANIA, A CORPORATION OF PENNSYLVANIA.

GENERATION OF CONVOLUTE LINES IN HOBBING CUTTERS AND THE LIKE.

1,426,680. Specification of Letters Patent. Patented Aug. 22, 1922.

Application filed April 10, 1918. Serial No. 227,784.

To all whom it may concern:

Be it known that I, OLIVER G. SIMMONS, now residing in the city and county of Philadelphia, in the State of Pennsylvania, have invented certain new and useful Improvements Relating to Generation of Convolute Lines in Hobbing Cutters and the like, of which the following is a specification.

This invention relates to a novel method of generating or forming, on the moulding principle of action, the convolute relieved teeth of hobbing cutters and of kindred articles of manufacture such as screws, taps, worms and the like, comprising lines of convolution, employed in the arts.

The general objects of my invention are, to produce articles of the character alluded to economically and of precise duplication by means of the conjugate action of a tool upon a blank, through evolution, by imparting certain motions to a tool and a blank and by differentially correlating the said motions, as will hereinafter appear.

The detail objects of my invention are to generate conjugate threads, or lines of convolute conjugate teeth upon the articles above referred to by imparting rotary motions to a cutter wheel or tool and the blank to be operated upon; by imparting a linear motion to either the cutter or the blank so rotated, or to both; by differentially correlating the motions aforesaid; by imparting a linear motion independent of the said differentially correlated motions; by imparting a reciprocating motion correlated with respect to the said rotary motions; by providing for the adjustment of the axis of rotation of one of the said rotary motions with respect to the axis of rotation of the other; and, by simultaneously coordinating the said motions substantially as hereinafter set forth.

The established practice followed in producing the threads of screws, taps, hobbing cutters and the like is to employ one or the other of the following well known methods viz.; of chasing the thread in a lathe by means of a form tool; of milling same in a suitable machine adapted for the purpose by means of a form milling cutter; of cutting by means of a form die; of rolling the threads by means of form rollers; and, lately of milling the thread by means of a hob, the length of which hob equals the cylindrical length of the screw to be cut completing the job of form milling the thread in one revolution of the work.

None of these methods has proven very satisfactory in the manufacture of hobbing cutters owing to the necessary relief or cutting clearance so vital in a cutter of this character. This work is usually done in a specifically constructed lathe by means of a relieving attachment adapted to receive a formed tool which is usually made according to fixed templets and arranged in the aforesaid attachment, with respect to the blank, by means of what may be termed a "centering gauge." As the very nature of this work compels close limits of error and which work is purely finishing, a keen cutting edge on the form tool can be maintained only by constant sharpening, which causes much delay and errors of workmanship resulting in a product of a very ununiform quality.

For obvious reasons a rotary form milling cutter is impractical on work of this nature.

To overcome the difficulties referred to, and to generate the thread, or lines of convolution, as distinguished from the forming operations alluded to, I provide the method forming the subject-matter of this invention in which the cutter is in constant intermeshing engagement with the thread being generated similar to the intermeshing of a worm wheel with a worm, in which, due to the convolutions of the thread of the worm, said thread will intermesh with every tooth of the worm wheel and will be the conjugate to the given teeth of the wheel. If the wheel is in the form of a cutter, it matters not what form is given to its cutting teeth, provided all of the teeth are of the given form, a conjugate tooth or thread will be generated in the worm, screw or hob, as will hereinafter be more fully described, by the intermeshing of the cutter and the blank on the moulding generating principle.

The drawings accompanying this specifi-

cation, it is understood, are for purposes of illustration only. The means herein shown are but a part of the many possible mechanisms for obtaining the differential resultant motion, between the cutter and the blank being operated upon, in the practice of my invention.

Referring now to the accompanying drawings,

Fig. 1, is a view in elevation and partly in quarter section of a tool or cutter generating conjugate teeth in an intermeshing worm according to one practice of my invention;

Fig. 2 is a section through a cutter and a hob generated and relieved thereby.

Figs. 3, 4 and 5 are views in elevation of an intermeshing cutter illustrating the action between said cutter and an intermeshing worm or hob before the gashes are cut, at the beginning of the work in Fig. 3; midway across in Fig. 4; and, finished in Fig. 5. These views illustrate my preferred practice. In Fig. 3, part of the worm or hob is broken away to show the bore;

Fig. 6, is an isometric projection illustrating a simple form of mechanism for practicing my invention;

Fig. 7, is a view in elevation of a cutter tool as it would appear when relieving conjugate teeth in an intermeshing hob in the practice of my invention. The cutter is shown as having finished one-half of the hob;

Fig. 8, is a vertical sectional view on line 8—8 of Fig. 7. In this view the cutter is shown at the position where the relieving cut begins, the hob and cutter rotating similarly to an intermeshing worm and worm wheel, the cutter meanwhile, slowly moving inward toward the axis of the hob, on a rectilinear line, jumping out quickly when the next gash is reached, whereupon the cutter again begins its inward movement, and so on in said cycles of movement until the said cutter, in intermeshing engagement moves across the face of the hob completing same; and,

Fig. 9, is similar to Fig. 8, illustrating the cutter as it would appear after having moved inward, in the rectilinear or relieving movement, to the position shown.

Referring to Fig. 1, the numeral 1 indicates a tool or cutter provided with edge cutting teeth radially projecting from the periphery of said cutter in which the cutting edge is in substantially a single plane, indicated by the numeral 2, which teeth are adapted to cut the thread 3, of the worm 4, when the said cutter and worm are each given a rotary motion equivalent to the intermeshing rotary motions of a worm and its mating wheel. It is obvious that if the worm 4 is to be provided with a single thread, the worm will make one revolution for every tooth of the cutter, one-half of a revolution if a double thread, for every tooth of the said cutter, and so on. In other words, if the worm is to be provided with a double thread, the cutter having one hundred teeth, the worm will make fifty revolutions to one revolution of the cutter.

In the illustration, Fig. 1, the teeth 3, of the worm, are shown as having been completed by the cutter 1. This has been accomplished by securing the cutter by means of the bore 5, and key-way 6, to the arbor of suitable apparatus in which apparatus is also secured the worm 4, by means of the bore 7, and key-way 8. By means of suitable gearing forming a part of the apparatus alluded to, one form of which will be more fully described later, the cutter 1, and the worm 4, are each given rotary motions; the worm in the direction of the arrow 9, and the cutter 1, in the direction of the arrow R for a right-hand worm, and in the direction of the arrow L for a left-hand worm. The cutter and worm thus are rotating about their respective axes with relative velocities equivalent to the relative velocities of an intermeshing worm and wheel equal in ratio to the ratio selected for the cutter and worm shown in Fig. 1. The rotating cutter is given a linear or more strictly a rectilinear motion by which the said cutter is "fed" into the rotating worm, by means of any suitable feed mechanism, whereupon the teeth 2, of the said cutter, generate the conjugate thread 3 of the worm. The action is continued until the desired depth of thread in the worm is attained when said worm may be replaced by another worm blank to receive similar treatment.

Obviously the cutter in the above described practice of my invention would have to be carefully centered with respect to the blank for the reason the peripheral surface of the worm would be in the form of a curve corresponding to the curved cutting surface of the cutter. The median line 10 of the worm, therefore, passes through the center 11, of the cutter. It is further obvious that the cutter selected would have to be at least as large as the largest wheel destined to mesh with the worm cut by said cutter, and that any wheel, of the given pitch, so long as it does not exceed the diameter of the cutter, would mesh properly with the mating worm cut by the said cutter.

It is evident that the measure of the length of a worm to be cut by the above method is limited to a cutting surface 12 and 13, of the teeth 2, of the cutter, being confined within parallel lines indicated by the numerals 14 and 15. These lines, if extended through the teeth of the cutter, would coincide with the side walls of said teeth, or be in coincidence with the outer-most points or edges of said walls, the balance of the walls of the teeth

towards the roots of the same, either being in coincidence with or inside of said parallel lines. Therefore, the opposite side walls of any two teeth in the cutter in parallelism determine the maximum permissible length of the worm 4 which may be cut without undercutting the teeth of said worm at the ends thereof.

It is to be observed that the high number of teeth 2, provided in the cutter 1, Fig. 1, results in a worm adapted to mesh with a wheel having any number of teeth up to and including, but not exceeding, a wheel provided with teeth, of the given pitch, equal in number of teeth to the number of teeth in the cutter. Other advantages than those already referred to will be fully explained later.

In the foregoing, no reference was made to the helix or the angle of same of the worm thread, for the reason in small pitches and medium large diameters, such as shown in Fig. 1, resulting thereby in a small helix angle, the same may be neglected as the usual cutting clearance provided in the cutter, indicated by the numeral 16, Fig. 2, is ample to clear the helix angle and present the cutting edge to the work. In coarse threads and small diameters however, it will be necessary to set the cutter, or the teeth of same, to the angle of the helix as is well understood by those familiar with this art. I wish it understood, however, that I am not limiting myself, in the practice of my invention, to any precise form of cutter which I may have selected as illustrative of the method. I prefer the cutter with the large number of teeth for the specific job shown in the illustrations referred to, and in general, the cutters illustrated in the drawings later referred to in detail, but these forms of cutters are not all of the modified forms of that type adaptable for use in my method, nor is it the only type adaptable as a cutter provided with teeth projecting from the periphery, for use according to my invention as those skilled in this art may comprehend.

It is now readily seen that the method previously described my be used in the manufacture of hobbing cutters for the generation of the teeth of spur and helical gear wheels.

In the art of gearing it is generally accepted that the type of tooth selected for the rack tooth is the key to the system and when said rack tooth is used as the generating tooth, to which adaptation the hob is particularly applicable, all gears cut by the said rack tooth will be interchangeable. It is evident, however, in the nature of things, that there must be some underlying reason for the adoption of a specific form of tooth for the rack. This appears outside the pale of the functions of mere designing, mechanical skill or a process of evolution. As referred to previously I prefer to employ a cutter having a large number of teeth, in the practice of my invention, when a hob provided with a curved surface is desired. The specific reason for this preference resides in the fact that the chordal pitch line thickness of a tooth of a gear, having one hundred and thirty-five teeth or more, so far as any manufacturing limits are concerned, is equal to the pitch line thickness of a tooth of a rack of the given pitch. If a cutter 1, Fig. 1, which is the equivalent of a gear wheel of one hundred and thirty-five teeth, is used as described, the teeth of said cutter will be the key to the system. The tooth elements of the cutter, therefore, will equal the tooth elements of the gear. The only difference between the cutter and the equivalent gear, lies in the cutting clearance provided in the former. A hob, therefore, cut by the cutter referred to, will have teeth conjugate to the teeth of said cutter, and all gears having one hundred and thirty-five teeth or less, cut by said hob, will be interchangeable and of the form adopted as the key to the system.

It is understood, of course, that a cutter having a greater number of teeth may be used with equal facility. It will be shown later how a smaller cutter may be used, in the practice of my invention, to generate convolute conjugate teeth or threads in hobs, worms, screws and kindred articles of manufacture.

Referring to Fig. 2, a fragmentary section of the cutter 1 is shown generating and relieving the flutes 17 of the hob 18. This is done to provide a cutting edge in the hob and is accomplished preferably by reciprocating the cutter slowly toward the center O, of the hob, during the cutting stroke, and rapidly away from said center, when the gash 19 is reached; the cutter and hob meanwhile, rotating about their respective axes in intermeshing engagement as previously described.

It is obvious that in the manufacture of hobbing cutters, by means of the invention herein disclosed, the gashes can be cut in the hob previous to the threading operation in which event the threading and relieving operations would be combined.

The above practice of my invention, I believe, is limited in its application to such articles of manufacture as the worm and the hob illustrated in Fig. 1 and Fig. 2 in which the curved surface appears to be an advantage owing to the greater number of teeth in contact. It is not my intention, however, to have such limited application. I prefer, therefore, in the general practice of my invention, to employ a cutter smaller than the cutter previously referred to and to overcome the limited application of the curve surface alluded to, I prefer to give an additional movement to the cutter or the blank, preferably to the cutter, which additional

movement combined with the rotary movements referred to previously, has as a resultant a differential as will hereinafter appear.

Referring to Figs. 3, 4 and 5, the numeral 20 indicates a cutter wheel provided with the cutting teeth 21, in intermeshing engagement with the thread 22, of the blank worm 23. The cutter 20 is seen to be much smaller than the cutter 1, Figs. 1 and 2, previously referred to as producing conjugate threads or teeth in a worm or hob, by a moulding principle of action, and similarly to which the cutter 20 will mouldingly generate conjugate threads or teeth in a worm, screw or hobbing cutter on cylindrical or other line surfaces. Any size cutter may be employed for this purpose as will hereinafter appear; though in the interest of economy, however, a small size cutter is preferable, all of which should have the same number of teeth for the various pitches, that is to say, the cutters are preferably provided with an equal number of teeth regardless of the pitch of same.

In Figs. 3, 4 and 5, the cutter illustrated has been provided with twenty teeth and as it is the equivalent of a gear wheel of the given pitch, all screws, worms or hobs generated by said cutter will be conjugate to the teeth of said cutter and all cutting tools such as hobbing cutters, for instance, which have been generated by the cutter referred to, will be capable of generating conjugate teeth in gear wheels, which will be interchangeable between the pinion and the rack of the given pitch.

In Fig. 3, the cutter is shown as having moved longitudinally part way across the face of the blank; in Fig. 4, the cutter is shown as having reached substantially the middle of the face of the blank in its longitudinal movement across said face; and, in Fig. 5, the cutter is shown as it would appear after passing across the face of the worm 23 completing same.

The above is accomplished by my method substantially as follows: The cutter 20 is provided with the bore 24 and the key-way 25 adapting same to be secured to an arbor in a machine adaptable for the purpose as will hereinfter appear. The worm 23 is provided usually with the bore 26 and the key-way 27 adapting same to be secured to an arbor or mandrel in the machine referred to. If now, the cutter 20 is set to the depth of thread desired in the blank 23, the cutter rotating about its axis, preferably in the direction indicated by the arrow 28, the blank 23 rotating about its axis, preferably in the direction indicated by the arrow 29; and a rectilinear longitudinal movement, with respect to the face of the blank being operated upon, is given to the said cutter, in the direction indicated by the arrow 30, Fig. 3, the movements referred to being of such differential correlation obtained by means of suitable gearing, or preferably, e. g., by the means to be later described, the cutter will mouldingly generate the conjugate thread in the work 23.

The above will become clear, it is believed, by assuming the cutter wheel, Figs. 3, 4 and 5, in mesh with a worm rotating about its axis but fixed with respect to any rectilinear or longitudinal movement, the wheel, however, being free to move longitudinally of the worm. As long, therefore, as the cutter wheel remains in the same longitudinal position with respect to the worm, the wheel will rotate in exact ratio with the worm, that is to say, if the cutter wheel has twenty teeth and the worm is provided with a single thread, the worm will make twenty revolutions while the cutter wheel makes but a single revolution. Moreover, if the intermeshing cutter wheel is given a linear movement longitudinally of the worm, with a velocity equal to the linear pitch of the worm, for every revolution of said worm, the cutter wheel will have a linear movement only, just as though the convolutions of the thread were moving the intermeshing wheel longitudinally of the worm. It follows further, that if the cutter wheel is given correlated linear and rotary movements with respect to the rotary movement of the worm, the differential correlation of the movements are infinite.

It is obvious that the action above described may be reversed to give the worm or blank being operated upon, the linear movement as well as the rotary movement, in which event the cutter could be provided with only a rotary movement.

It is further obvious that a combination of the linear and rotary movements may be provided for in both the cutter and the blank being operated upon and obtain equally as good results so long as the differential correlation of the movements is maintained.

The preferred means previously referred to, are illustrated in Fig. 6. The view is an isometric projection, showing in perspective, only such parts of the apparatus as are required to demonstrate how I obtain, in a very simple way, the differential correlation and the several motions referred to.

Referring to Fig. 6, the numeral 31 indicates an arbor, shaft or mandrel adapted to receive and secure a hob, worm or other blank 46 to be operated upon as will later appear. The numeral 32 indicates a gear wheel secured by any suitable means to one end of the mandrel 31 and adapted to engage an intermediate gear indicated by the numeral 33, which intermediate gear engages also, a gear indicated by the numeral 34, to which gear is adapted to be secured the worm-shaft 35, by any suitable means.

The numeral 36 indicates the right-hand thread of the worm-shaft 35, which thread has intermeshing engagement with the worm-wheel 37, to which is secured, by any suitable means, a shaft indicated by the numeral 38. One end of the shaft 38 is bored and key-seated adapting same to slidingly receive the shaft 39, which is provided with the key 40, adapting the said shaft 39 to reciprocate in and be rotated by the said shaft 38. The numeral 41 indicates a miter gear secured to and forming a part of the shaft 39. A counterpart miter gear 42 engages the similar miter gear 41, the same being secured to and forming a part of the shaft 43, to which, at the end of same, is secured the toothed cutter wheel 44, by means of the nut 45, which has threaded engagement with the said shaft 43. It is obvious that the said shaft 43, is adapted to rotate about its axis, at any angular position with respect to the mandrel 31, by virtue of the engaging miter gears 41 and 42. The miter gears are so defined for the reason they each have an equal number of teeth which is the ratio I prefer, in the interest of simplicity, for these gears.

It is assumed the shafts 31, 35, 38, 39 and 43 are supported in suitable bearings of a machine adapted to receive same and to permit the angular adjustment of the cutter secured on shaft 43, and contained within said machine are the means to support the idler intermediate gear 33, all as later described. Obviously I could substitute a compound train of gears for the idler gear and obtain, by these means, any ratio of rotation between the shafts 31 and 35. The same reason, however, which applied to the bevel gears 41 and 42, is applicable in this connection and in the interest of simplicity, I have selected the simplest form and have provided the gears 32 and 34 with an equal number of teeth.

It is now evident that whatever the intermeshing relation is, between the cutter and the work, it must be obtained through the medium of the worm-shaft 35 and the worm-wheel 37. Any worm-wheel and worm-shaft, which will give the ratio of the relation referred to, would be satisfactory. This relation is determined when the number of teeth in the cutter and the number of threads desired in the blank are known. Therefore, let it be assumed that the cutter is provided with twenty-one teeth and that a single thread is desired in the blank, the ratio, therefore, of the worm-shaft 35, and the worm-wheel 37, is as twenty-one is to one, so that, if the worm-shaft is provided with a single thread, the worm-wheel will be provided with twenty-one teeth which will give the desired ratio. I have provided, therefore, for the purpose of the demonstration, a cutter 44 with twenty-one teeth; the worm-shaft 35 with a single right-hand thread 36, and, the worm-wheel 37, with twenty-one teeth, since it is desired that a single thread be generated in a blank, indicated by the numeral 46, which blank may be secured to the mandrel 31, by any suitable means.

The illustration, Fig. 6, shows the working parts as they would appear after completing the thread 47 of the blank or worm 46.

On the assumption that the cutter has reached the position shown, after completing its "cut", and the shafts are all at rest, it is obvious that the housing H supporting the cutter and driving mechanism, to include only the worm-wheel 37, shafts 38 and 39, bevel gears 41 and 42, shaft 43 and the cutter 44, may be moved, as an unitary part, on any suitable base or guides B, B, longitudinally of the parallel shafts 31 and 35, and in which movement, the cutter 44 and the worm-wheel 37, would have rotary as well as linear movements, since the worm-wheel 37 has intermeshing or rolling engagement with the worm-shaft 36 and, likewise, the cutter will intermesh and engage the thread 47 which the said cutter 44 previously generated, in the longitudinal and linear movements referred to.

The elements of the unitary part referred to are provided, as hereinbefore stated, with suitable bearings and means for permitting angular adjustment of the cutter. The worm-wheel 37 and shaft 38 have a bearing 38^a supported on the aforementioned housing. The shaft 39 and miter gear have a bearing 39^a on the member C movable transversely to the shafts 31 and 35 on the housing. The shaft 43 and cutter 44 have a bearing in the member 43^a adjustable on member 39^b, as by bolt 43^c extending through slot 43^b, to effect the angular adjustment of the cutter and its shaft as above referred to.

It is obvious that the linear longitudinal movement of the unitary part consisting of worm-wheel 37, shafts 38, 39, gears 41, 42, shaft 43 and cutter 44 carried as a unit by a housing, as H, may be of any desired speed or velocity and is selected independently of the rotary movements or absence of same in the shafts 31 and 35. This holds true because the differential correlation of the movements are automatically taken care of in the form of apparatus illustrated.

It was deemed advisable to set forth the above automatic feature of taking care of the differential, in the practice of my invention, before the actual operation of generating the thread 47, of the worm 46, was described.

In this description it will be necessary to assume that the unitary part, above referred to, is at the other end of the worm 46, from that shown in Fig. 6. In other words, the cutter 44, of any given pitch, for a right-hand worm, is placed at the right-hand end

of the blank as indicated by the numeral 48.

The gear 32 is assumed to be driven by any suitable means to rotate in the direction of the arrow 49, driving the engaging idler gear 33, in the opposite direction as indicated by the arrow 50. The idler gear engages and drives the worm shaft gear 34 in the direction indicated by the arrow 51, which is seen to be in the same direction of rotation as the gear 32. The worm shaft being secured to the gear 34, will rotate in the same direction as the said gear as indicated by the arrow 52. The right-hand thread 36, of the worm-shaft will rotate the intermeshing worm-wheel 37, in the direction indicated by the arrow 53, driving the secured shaft 38 in the same direction as indicated by the arrow 54. The bevel gear 41, being secured to the spline shaft 39, which shaft is adapted to slidingly engage the bore in the shaft 38, and be rotated by it, by means of the key 40, slidingly engaging a key-way in said bore, will drive the said bevel gear in the same direction as indicated by the arrow 55. The shaft 43, therefore, being secured to the bevel gear 42, which has intermeshing engagement with the bevel gear 41, will be driven by said gear 41, in the direction indicated by the arrow 56. Hence, the shaft 43 and the cutter 44, which is secured to same, will rotate in the direction indicated by the arrows 56, 57 and 58.

If, now, the cutter 44, is moved in to the required depth of the thread 47 desired in the worm or blank 46, as by moving member C on member H as by handle *h* as in ordinary machine tools, and the unitary part slowly moved, similar to the feed motion in any machine tool employing a cutting tool, as by feed screw F engaging housing H by nut *f*, across the face of the blank, in the direction indicated by the arrow 59, the cutter 44, will mouldingly generate a conjugate thread in the blank 46 by means of differential correlated movements.

When the cutter and the unitary part reach the position shown in the drawing, the feed is stopped, as by operating nut *f* to free housing H from feed screw F, the finished worm removed and a new blank is secured to the mandrel 31 to be operated upon as previously described, the cutter is moved out, to be out of contact with the blank, and the unitary part returned to the orginal position or starting point, as at the end indicated by the numeral 48. The cutter is now ready to be again moved in, in a rectilinear path, to the required depth of thread desired in the worm and when this is done, the feed may be thrown in, whereupon the unitary part begins again to operate, upon differential correlated movements, so arranged that any cutter adaptable to the work, will automatically generate the conjugate thread in the blank.

It is obvious that if a feed is selected which is equal to the circular pitch of the cutter, the unitary part, during the operation of the mechanism employed, would have a linear movement only. That is to say, if the shafts 31 and 35 are rotating and a linear movement or lead, equal to the circular pitch of the cutter 44, be given to the unitary part, so as to move said part in the direction of the arrow 59, for a right-hand convolution, the worm-wheel 37 and the cutter 44, will have linear movement only for the reason that the linear advance of the thread 36, of the worm-shaft 35, will be equal to the linear movement or lead, given to the said unitary part.

The above is a function of the apparatus, which, together with the function of the unitary part having rotary movement only, previously referred to, and the infinite differential correlated movements, also referred to previously, proves the truth of the principle involved underlying the invention.

It is obvious that to generate left-hand convolutions, it is only necessary to reverse the direction of rotation of the shaft 35 from that indicated by the arrow 51, which will cause the cutter 44 to rotate in the direction opposite to that indicated by the arrow 58, and in which event, it is evident, the cutter will begin work on the end opposite to the end indicated by the numeral 48.

The above may be obtained by introducing another idler gear (not shown) between the gears 33 and 34 and with which gears it will be adapted to engage.

The spline shaft 39, Fig. 6, which permitted the cutter to be moved to the desired depth of the thread in the blank and away from said blank preparatory to taking a new cut, has other functions as will presently appear in connection with the relieving of the teeth of hobbing cutters, previously referred to, and which is illustrated in the drawing Figs. 7, 8 and 9 to which I now refer.

The hob 60, Fig. 7, is shown as having been threaded previous to the relieving operation, which is now assumed to be taking place in the view referred to. The separations of these operations, which may be combined as referred to, has been done so as not to confuse or complicate the description of the method needlessly. The cutter 61, therefore, in addition to the differential correlation of the movements, will have a reciprocating movement toward and away from the axis of the hob 60, to relieve the teeth of same on the moulding generating principle of action to produce the conjugate teeth referred to previously. The numeral 62, Fig. 7, indicates a center line of the cutter 61, when same is in substantially the normal position or the position the cutter would have, if the said cutter was set to the depth

of the tooth in the worm, as in generating the thread in the blank previously described. The line 63 indicates the position of the center line 62, when the cutter 61 reaches its inmost position just before it begins the rapid return stroke. The measure of the distance between the lines 62 and 63, would be the amount of the relief which usually is expressed in fractions of an inch and which is easily obtained by means of any one of many well known attachments. For example, cam *b*, rotating in direction of arrow *c* at suitable speed, forces member *d* attached to member C toward the right slowly for moving the cutter slowly inward, and when the highest part of the cam passes member *d* the latter and the cutter are rapidly moved outward by spring *e;* and this cycle is repeated for each flute of the hob.

For the purpose of this specification, therefore, I believe it only necessary to state that the cutter has a slow linear inward movement while in contact with the flutes and a rapid linear outward movement when the gashes are reached, this, of course, takes place simultaneously with the intermeshing movements of the cutter and the hob. The relief of the teeth is clearly seen by contrast with the concentric line indicated by the numeral 64. This relief is again apparent in Fig. 9, in which the curved line 65 is concentric with the hob 60. In this view, the cutter 61 is shown as having moved partly inward, on the slowly moving cutting stroke, and amount indicated by the numeral 66, as the measure of the distance between the normal center line 62, and the center line of the cutter in the position shown. It is obvious that the out-stroke, or the rapid return of the cutter to normal position, takes place after leaving the flute 67 and that it will be back in the normal position by the time the next flute, indicated by the numeral 68, approaches contact, whereupon, at said contact, or slightly before same is preferable, the cutter begins its slow linear inward movement as previously described.

Obviously the quick return stroke can take place only in the gashes, indicated by the numeral 69, of the hob 60, and it is further obvious that by means of the train of gears provided in the relieving attachments referred to previously, I can gear up said attachments to relieve hobs gashed on a helical curve, which curve is usually perpendicular to the helix of the thread convolutions at the pitch line of the hob.

The above becomes necessary as previously referred to, when small diameter hobs are provided with coarse threads; more definitely, and in general, when the angle of the helix exceeds substantially an angle of three degrees.

It is now apparent why the spline shaft 39 was provided in the apparatus illustrated in Fig. 6, by means of which I am enabled to reciprocate the cutter, for the purpose of relieving the intermeshing teeth, without in any way interfering with the differential correlation of the movements of the cutter and the blank.

In small diameters and coarse threads, to which I have alluded, it will be necessary to set the cutter to the helix of the thread. For this purpose I preferably provided that the cutter shaft 43, Fig. 6, be driven by means of the bevel gears 41 and 42, and by means of which arrangement, the cutter 44 can be angularly adjusted to correspond to the angle of the helix for any given hob, whether of coarse or of fine thread, and which angular adjustment, it is obvious, will be about the shaft 39, by moving the shaft 43 to desired position and holding it by clamping the member 43^a by bolt 43^c, and when so adjusted to position, will cause the cutter to present its working face, which face may be considered as a disk or a circular plane, substantially perpendicular to the helical curve selected or determined, without conflicting with the differential correlation of the rotary and linear movements of the cutter and the blank.

It is understood, of course, by those skilled in the art of cutting metals, that the median cutting point of the cutter 44, Fig. 6, will be on a radial line of the blank being operated upon and which line will also be a center line of the cutting face of said cutter. By median cutting point I mean the cutting point that approaches nearest the axis of the said blank. Whatever adjustment of the cutter is necessary, said adjustment being longitudinally of the shaft 43, to obtain the above condition, is easily accomplished by the means of an adjustable screw washer placed between the cutter and a shoulder of the said shaft 43, with which shaft, due to the angular adjustability of same, previously referred to, the cutter will be capable of being adjusted longitudinally of the said shaft, to meet the well known requirements above referred to.

It is obvious that the correlation of the differentials is automatic in the apparatus.

It was previously stated that the differential movements could be obtained by means of gearing arranged in the form of a train of gears, similar to the change gearing arrangement in many machine tools in some of which, a differential may enter and is provided for by means of two or more distinct trains of gearing, adaptable to function independently when a differential does not enter, but which must be geared with respect to one another, with definite factors, thus correlating them for the given factors, when a differential enters and is to be provided for.

The factors above referred to are fixed

for any particular differential. One factor cannot be changed without regard for the other factors for a given differential. In other words, for any given differential, the factors must be arranged in correlation for the variable of the given differential, and any change in either the differential or the correlation of the said factors, will produce a change in the other.

By the expression differential correlation, I mean, therefore, that the infinite differential possible in the practice of my invention, between the cutter and the blank being operated upon, may be correlated as previously described, by the means of change gears in two or more trains of gears or by the means of automatic correlation through the medium of the unitary part.

A housing H, Fig. 6, movable by a feed screw F longitudinally on a base or guides B, B, and having a transversely movable member C carrying a cutter and operable by a handle *h* and also by a relieving attachment, is old in the art of machine tools and is not, per se, my invention, but—

What I claim is:

1. A method for generating threads of convolution, which consists in imparting rotary motions to a cutter provided with radial teeth projecting from its periphery in substantially a plane of rotation, and to a blank to be operated upon, functionally correlating the said rotary motions and simultaneously with the rotary motions of the cutter and the blank producing relative rectilinear reciprocating movement between the cutter and the blank.

2. A method of generating convolute lines of edged teeth in a blank, which consists in simultaneously imparting rotary motions to a tool and a blank to be operated on by said tool and functionally correlating said motions, producing relative reciprocating motion between the tool and the blank functionally correlated with respect to the rotary motions thereof, and in producing relative rectilinear motion between said tool and blank, independent of said correlated motions.

3. A method for obtaining convolute lines of relieved teeth in a blank, which consists in simultaneously imparting rotary motions to a tool and a blank acted on by said tool and functionally correlating said motions, imparting a reciprocating motion to the tool functionally correlated with respect to the rotary motion of the blank, imparting a rectilinear motion to the said tool along the blank, independent of the said correlated motions, and continuing the said motions to produce convolute lines of relieved teeth in the blank aforesaid.

4. A method for generating convolute lines in a blank, which consists in simultaneously imparting rotary motions to a tool the face of which tool is substantially perpendicular to the helical lines of convolution and a blank to be acted upon by said tool, imparting rectilinear motion to said tool simultaneously with the rotary motions of the tool and blank, and differentially correlating the said motions.

5. A method for generating convolute lines in a blank, which consists in simultaneously imparting rotary motions to a tool and a blank to be acted on by said tool, the plane of the cutting face of which tool is substantially perpendicular to the lines of convolution of said blank, imparting rectilinear motion to said tool along a line substantially parallel to the axis of rotation of said blank, and differentially correlating the said motions.

6. A method for generating convolute lines in a blank, which consists in simultaneously imparting rotary motions to a tool and a blank to be acted on by said tool, said rotary motions being about axes angularly adjustable with respect to each other, simultaneously producing relative rectilinear motion between the tool and the blank, and automatically correlating the differential of the variable of the said motions.

7. A method for generating convolute lines in a blank, which consists in simultaneously imparting rotary motions to a tool and a blank to be acted on by said tool, producing relative motion of said tool along said blank, and producing a relative reciprocating motion between said tool and blank.

8. A method for generating relieved teeth in a hob, which consists in simultaneously imparting rotary motions to said hob and a cutter acting thereon, imparting rectilinear motion to said cutter, differentially correlating the said motions and producing a relative reciprocating motion between the cutter and the hob, said reciprocating motion being definitely correlated to the said rotary motion of the hob and differentially correlated to the rotary motion of said cutter.

9. A method for generating convolute relieved teeth in a hob which consists in simultaneously imparting rotary motions to the hob and to an intermeshing cutter, imparting a rectilinear motion to said cutter, differentially correlating the motions aforesaid and producing a rectilinear reciprocating motion to the said cutter functionally correlated with respect to the rotary motion of the hob.

10. A method for generating convolute lines in a blank, which consists in simultaneously imparting rotary motions to a cutter provided with teeth conjugate to the convolute lines desired in a blank and intermeshing with said blank, and to said blank, producing relative rectilinear motion between the cutter and blank, and differen-

tially correlating the said rotary and linear motions automatically, whereby the teeth of the cutter will produce their conjugate on convolute lines in the blank.

11. A method for generating lines of convolute conjugate teeth, which consists in simultaneously imparting rotary motions to a blank to be operated upon and to a cutter wheel intermeshing with the blank, producing a relative feed movement between the cutter and the blank simultaneously with the rotary motions aforesaid, producing relative rectilinear motion between the cutter and blank in a direction longitudinally of the face of said blank, differentially correlating said rotary motions and said rectilinear longitudinal motion, and producing a relative reciprocating motion between the cutter wheel and the blank independently of said rectilinear motion and functionally correlated with respect to the said rotary motions, the said rotary motions being about axes adjustably disposed to each other.

12. In an apparatus of the class described, in combination with a cutter in the form of a wheel, having teeth provided with edged cutting faces, means for rotatably supporting a blank in co-operative relation with said cutter, means for simultaneously rotating said cutter and blank, and means for producing relative reciprocating movement between the cutter and the blank to cause said cutter to generate in the blank relieved teeth of a given pitch.

13. In an apparatus of the character described, in combination with a rotatable mandrel for holding a blank to be cut, a cutter rotatably mounted to act upon said blank, means for simultaneously rotating the cutter and blank, means for producing relative movement of the cutter along the blank simultaneously with the rotary motions thereof, and means for producing a relative reciprocatory movement between said cutter and blank simultaneously with said rotary motions.

14. The method of generating a relieved thread in a gashed blank, which consists in rotating the blank and a cutter on axes substantially at right angles to each other, and for each gash of the blank simultaneously feeding the cutter into and withdrawing it from the blank.

15. The method of producing a hob, which comprises gashing a blank, generating a thread therein by rotation of the blank and a cutter on axes substantially at right angles to each other, and for each gash feeding the cutter into and withdrawing it from the blank.

16. The method of producing a hob, which comprises gashing a blank, generating a thread in the blank and a surface between threads terminating at a gash to form a cutting edge continuous with the cutting edge formed by the intersection of the thread with the gash by rotating the blank and cutter on axes substantially at right angles to each other, feeding the cutter into the blank to a depth less than the depth of the gashing, and for each gash feeding the cutter into and withdrawing it from the blank for relieving the thread and said surface.

17. The method of generating a relieved thread in a gashed blank, which consists in rotating the blank and a cutter on axes substantially at right angles to each other, and for each gash of the blank simultaneously feeding the cutter into and withdrawing it from the blank, and moving the cutter longitudinally with respect to the blank.

18. The method of producing a hob, which comprises gashing a blank, generating a thread therein by rotation of the blank and a cutter on axes substantially at right angles to each other, and for each gash feeding the cutter into and withdrawing it from the blank, and moving the cutter longitudinally with respect to the blank.

19. The method of producing a hob, which comprises gashing a blank, generating a thread in the blank and a surface between threads terminating at a gash to form a cutting edge continuous with the cutting edge formed by the intersection of the thread with the gash by rotating the blank and cutter on axes substantially at right angles to each other, feeding the cutter into the blank to a depth less than the depth of the gashing, for each gash feeding the cutter into and withdrawing it from the blank for relieving the thread and said surface, and moving the cutter longitudinally with respect to the blank.

20. The method of generating a relieved thread in a gashed blank, which consists in rotating the blank and a cutter on axes substantially at right angles to each other, for each gash of the blank while the cutter is rotating feeding the cutter into and withdrawing it from the blank, and moving the cutter longitudinally with respect to the blank a plurality of times for successive cuts.

21. The method of producing a hob, which consists in generating a thread in a hob blank by rotating the blank and a cutter on axes substantially at right angles to each other, simultaneously feeding the cutter into the blank for relieving the thread, and moving the cutter longitudinally with respect to the blank a plurality of times for successive cuts.

22. The method of producing a hob, which comprises gashing a blank, generating a thread in the blank and a surface between threads terminating at a gash to form a cutting edge continuous with the cutting edge formed by the intersection of the thread with the gash by rotating the blank and cutter on axes substantially at right angles to

each other, feeding the cutter into the blank to a depth less than the depth of the gashing, for each gash feeding the cutter into and withdrawing it from the blank for relieving the thread and said surface, and moving the cutter longitudinally with respect to the blank a plurality of times for successive cuts.

23. The method of generating a relieved thread in a gashed blank, which consists in rotating the blank and a cutter on axes substantially at right angles to each other, for each gash of the blank simultaneously feeding the cutter into and withdrawing it from the blank, and moving the cutter longitudinally with respect to the blank with its speed of rotation differentially correlated to that of the blank.

24. The method of producing a hob, which consists in generating a thread in a hob blank by rotating the blank and a cutter on axes substantially at right angles to each other, simultaneously feeding the cutter into the blank for relieving the thread, and moving the cutter longitudinally with respect to the blank.

25. The method of producing a hob, which comprises gashing a blank, generating a thread therein by rotation of the blank and a cutter on axes substantially at right angles to each other, for each gash feeding the cutter into and withdrawing it from the blank, and moving the cutter longitudinally with respect to the blank with its speed of rotation differentially correlated to that of the blank.

26. The method of producing a hob, which comprises gashing a blank, generating a thread in the blank and a surface between threads terminating at a gash to form a cutting edge continuous with the cutting edge formed by the intersection of the thread with the gash by rotating the blank and cutter on axes substantially at right angles to each other, feeding the cutter into the blank to a depth less than the depth of the gashing, for each gash feeding the cutter into and withdrawing it from the blank for relieving the thread and said surface, and moving the cutter longitudinally with respect to the blank with its speed of rotation differentially correlated to that of the blank.

27. The method of generating a thread in a blank, which consists in rotating the blank, and rotating a cutter on an axis displaced from 90 degrees with respect to the axis of rotation of the blank by an amount bringing the plane of rotation of the cutter normal to the thread as it is generated.

28. The method of generating a relieved thread in a blank, which consists in rotating the blank, rotating a cutter on an axis displaced from 90 degrees with respect to the axis of rotation of the blank by an amount bringing the plane of rotation of the cutter normal to the thread as it is generated, feeding the cutter into and withdrawing it from the blank for relieving the thread, and moving the cutter longitudinally with respect to the blank.

29. A hob having generated relieved teeth.

30. A hob having generated relieved teeth, and generated relieved surfaces between teeth, said surfaces at their intersections with the gashes forming cutting edges.

31. A gashed cutter having generated relieved teeth.

32. A cutter having helically disposed generated relieved teeth.

33. Apparatus for producing generated relieved teeth in a blank, comprising means for rotating the blank, a cutter rotatable about an axis substantially at right angles to the axis of rotation of the blank, means for rotating said cutter, and means automatically feeding the cutter into and withdrawing it from the blank for relieving the teeth.

34. Apparatus for producing generated relieved teeth in a blank, comprising means for rotating the blank, a cutter rotatable about an axis substantially at right angles to the axis of rotation of the blank, means for rotating said cutter, means automatically feeding the cutter in a straight line into and withdrawing it from the blank for relieving the teeth, and means for moving the cutter longitudinally of the blank.

35. The combination with means for rotating a blank, of a worm extending parallel with the axis of the blank, means for rotating said worm, a worm gear driven by said worm, a cutter rotatable about an axis substantially at right angles to the axis of rotation of the blank, a driving connection between said worm gear and said cutter, and means reciprocating said cutter in a rectilinear path toward and away from the blank.

36. The combination with means for rotating a blank, of a worm extending parallel with the axis of the blank, means for rotating said worm, a worm gear driven by said worm, a cutter rotatable about an axis substantially at right angles to the axis of rotation of the blank, a driving connection between said worm gear and said cutter, means reciprocating said cutter toward and away from the blank, and means for moving said cutter longitudinally of the blank.

37. Apparatus for producing generated relieved teeth in a blank, comprising means for rotating the blank, a cutter rotatable about an axis substantially at right angles to the axis of rotation of the blank, means for rotating said cutter, means for feeding the cutter in a straight line into and with-

drawing it from the blank, and means for moving the cutter longitudinally of the blank, the plane of rotation of said cutter being disposed normal to the tooth helix.

38. The combination with means for rotating a blank, of a worm extending parallel with the axis of the blank, means for rotating said worm, a worm gear driven by said worm, a cutter rotatable about an axis substantially at right angles to the axis of rotation of the blank, a driving connection between said worm gear and said cutter, means reciprocating said cutter toward and away from the blank, and means for moving said cutter longitudinally of the blank, the plane of rotation of said cutter being disposed normal to the tooth helix.

39. The combination with means for rotating a blank, of a rotatable shaft whose axis is at an angle to the axis of rotation of said blank, a second shaft splined to said shaft and driven thereby, a cutter rotatable about an axis approximately at right angles to the axis of rotation of said blank, a driving connection between said second shaft and said cutter, and means for reciprocating said cutter longitudinally of said first named shaft toward and away from said blank in timed relation to the speed of said blank.

40. The combination with means for rotating a blank, of a rotatable shaft whose axis is at an angle to the axis of rotation of said blank, a second shaft splined to said shaft and driven thereby, a cutter rotatable about an axis approximately at right angles to the axis of rotation of said blank, bevel gears connecting said second shaft to said cutter whereby said cutter is driven by said second shaft and is adjustable about the axis of said second shaft, and means for reciprocating said cutter longitudinally of said first named shaft toward and away from said blank in timed relation to the speed of said blank.

41. The combination with means for rotating a blank, of a rotatable shaft whose axis is at an angle to the axis of rotation of said blank, a second shaft splined to said shaft and driven thereby, a cutter rotatable about an axis approximately at right angles to the axis of rotation of said blank, a driving connection between said second shaft and said cutter, means for reciprocating said cutter longitudinally of said first named shaft toward and away from said blank in timed relation to the speed of said blank, a gear fixed to said first named shaft, means extending lengthwise of said blank engaging the teeth of said gear, and means for moving said cutter, said shafts and said gear as an unitary part lengthwise of said blank.

42. In a machine for producing hobs, a cutter resembling a bevel gear, a work holder adapted to rotate the work in such direction that the portion momentarily in contact with the cutter moves approximately perpendicularly to the plane of the cutter, positive acting means for rotating the cutter at a peripheral speed equivalent to the lead of the hob teeth and means operating in timed relation with the work holder for periodically and automatically moving the cutter approximately radially toward and from the work.

43. In a machine tool a multiple tooth cutter resembling a gear wheel, a work holder adapted to rotate the work in such direction that the portion momentarily in contact with the cutter moves approximately perpendicular to the plane of the cutter, means for feeding the cutter bodily in a direction parallel with the axis of the work, means for simultaneously rotating the cutter about its axis, and means for periodically moving the cutter bodily approximately radially toward and from the work.

44. In a screw cutting and relieving machine, a multiple tooth cutter resembling a bevel gear wheel, a work holder adapted to rotate the work in such direction that the portion momentarily in contact with the cutter moves approximately perpendicular to the plane of the cutter, means for feeding the cutter bodily in a direction parallel with the axis of the work, means for simultaneously rotating the cutter about its axis, and means operating in timed relation with the work holder for simultaneously and automatically reciprocating the cutter toward and from the work.

45. A hob cutting machine, having a work holder adapted to rotate the blank about its axis, a multiple tooth cutter resembling a gear wheel, the axis of the work lying approximately in the plane of rotation of the cutter, a carriage for causing the cutter to travel lengthwise of the work, a lead screw arranged parallel with the axis of the work, a worm gear connected to the cutter for rotating it, said cutter cooperating with the lead screw to roll along it and to be simultaneously rotated by it, and means for simultaneously reciprocating the cutter toward and from the work.

Signed this 8th day of April, 1918.

OLIVER G. SIMMONS.