July 30, 1940. E. STUBBS 2,209,483

METHOD AND MEANS FOR FINISHING RECESSES

Filed March 7, 1938 4 Sheets-Sheet 1

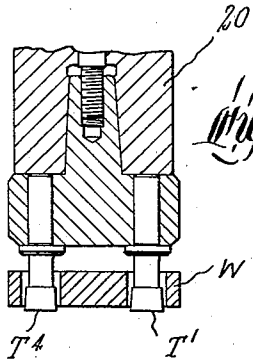


Fig. 1.

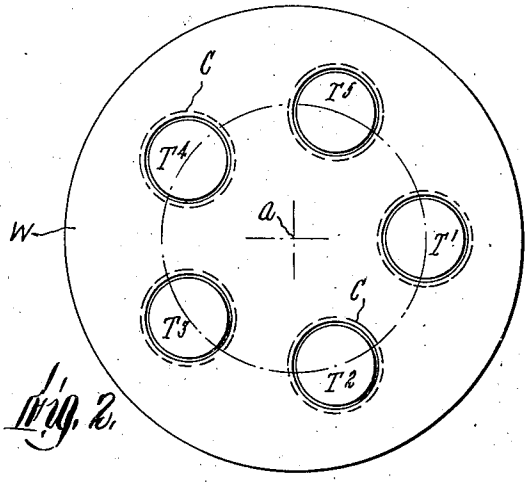


Fig. 2.

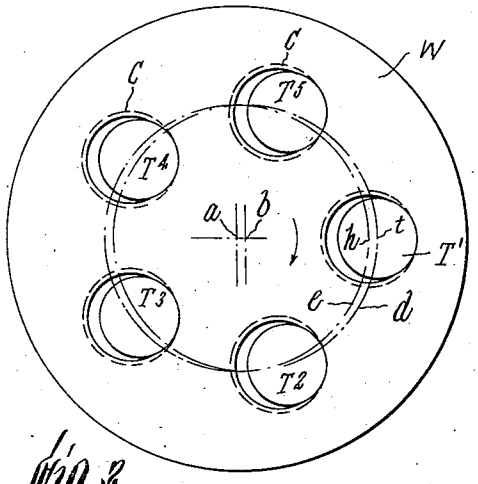


Fig. 3.

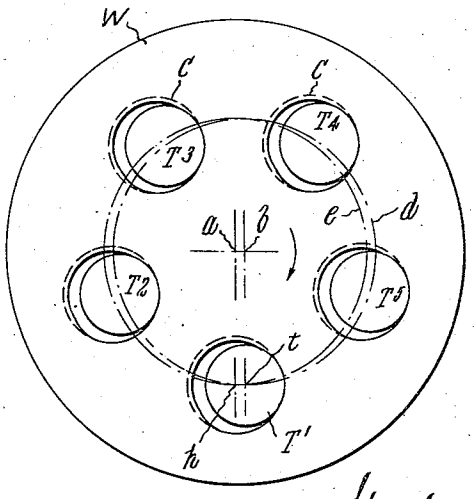


Fig. 4.

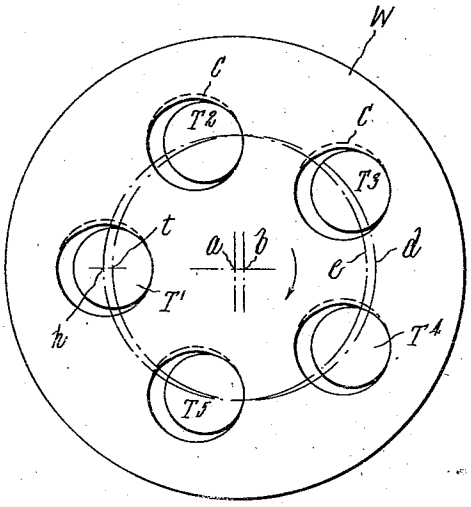


Fig. 5.

Inventor
Everard Stubbs
by Wright, Brown, Quinby & May
Attys.

July 30, 1940. E. STUBBS 2,209,483

METHOD AND MEANS FOR FINISHING RECESSES

Filed March 7, 1938 4 Sheets-Sheet 2

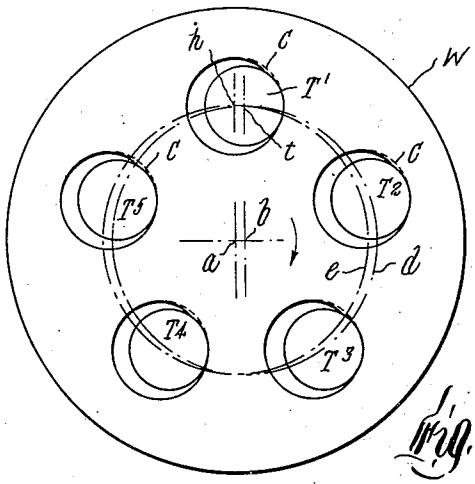


Fig. 6.

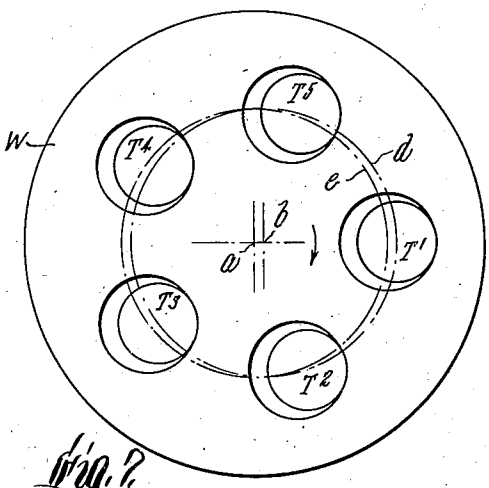


Fig. 7.

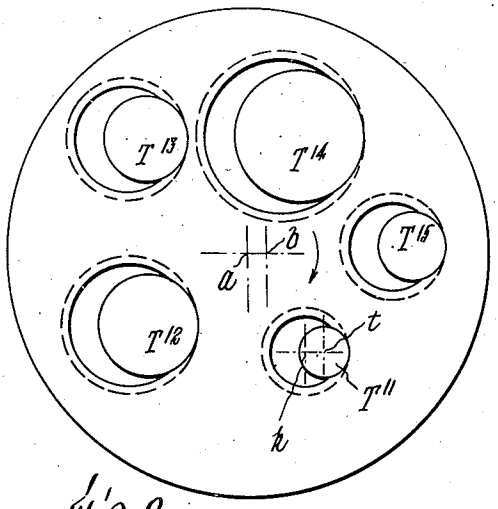


Fig. 8.

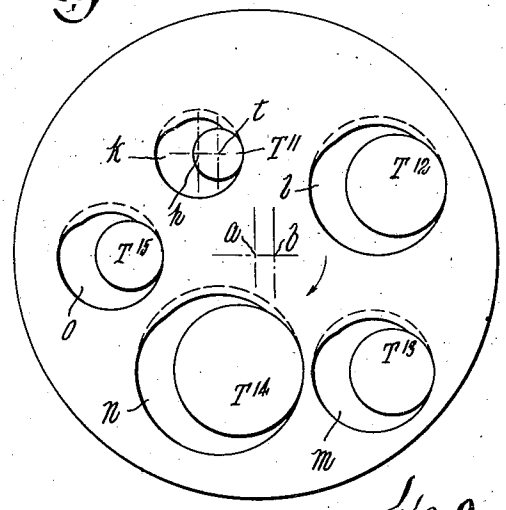


Fig. 9.

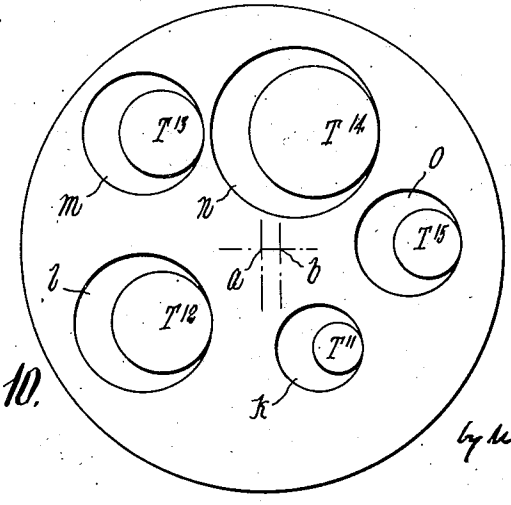


Fig. 10.

Inventor
Everard Stubbs
by Wright, Brown, Quinby & Macy
Attys.

July 30, 1940. E. STUBBS 2,209,483

METHOD AND MEANS FOR FINISHING RECESSES

Filed March 7, 1938 4 Sheets-Sheet 3

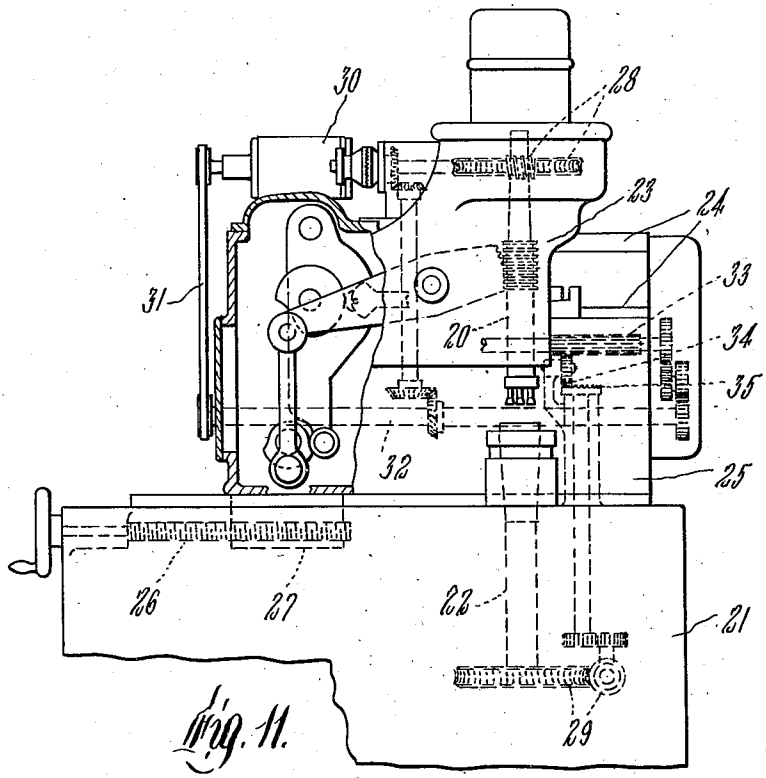
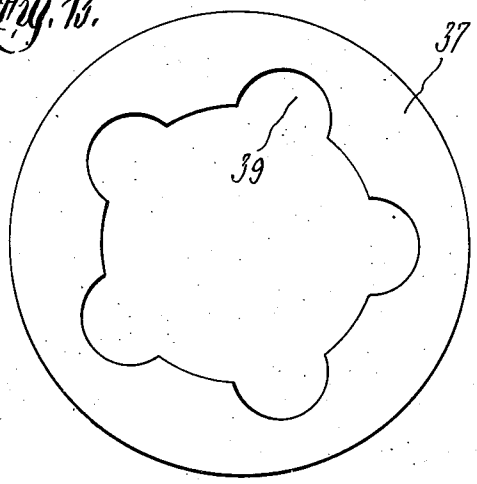


Fig. 11.

Fig. 13.



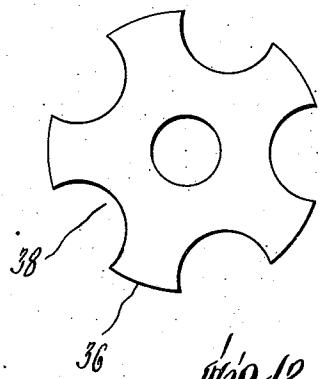


Fig. 12.

Inventor
Everard Stubbs
by Wright, Brown, Quinby & Hoag
Attys.

July 30, 1940. E. STUBBS 2,209,483

METHOD AND MEANS FOR FINISHING RECESSES

Filed March 7, 1938 4 Sheets-Sheet 4

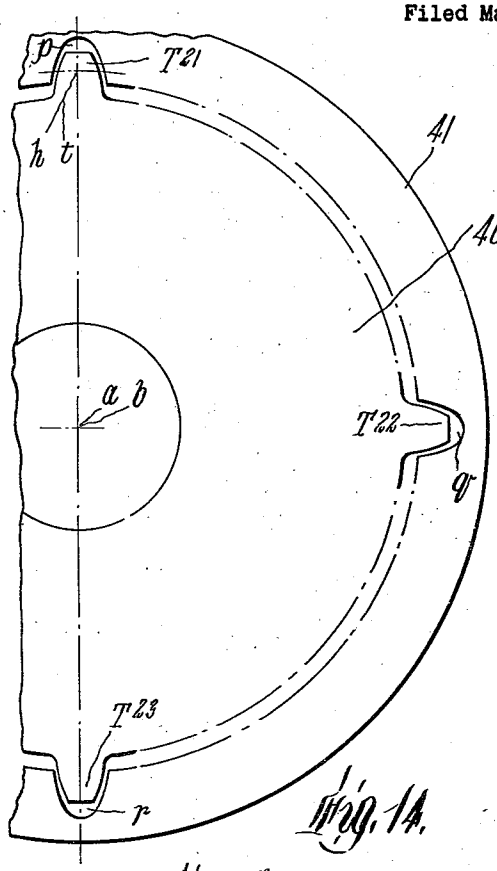


Fig. 14.

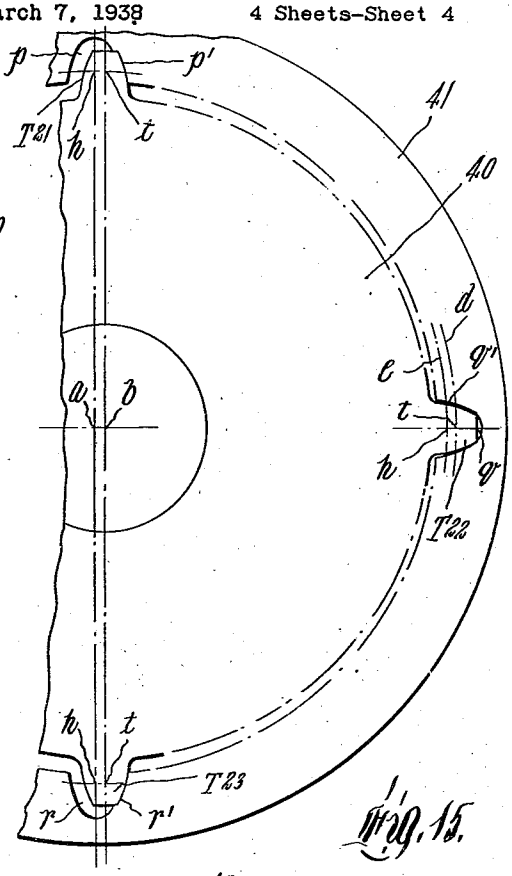


Fig. 15.

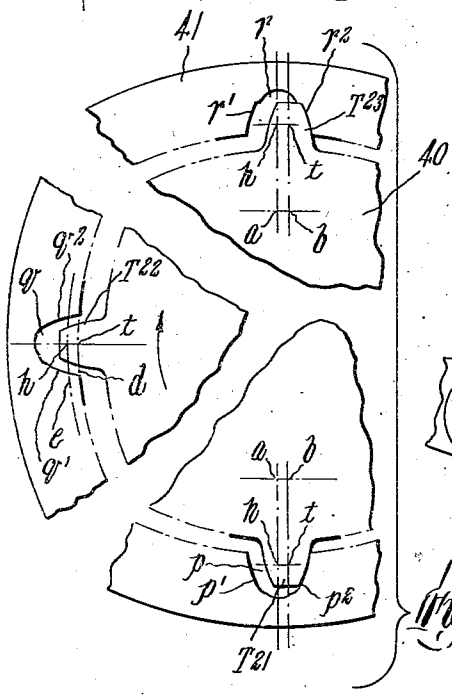


Fig. 16.

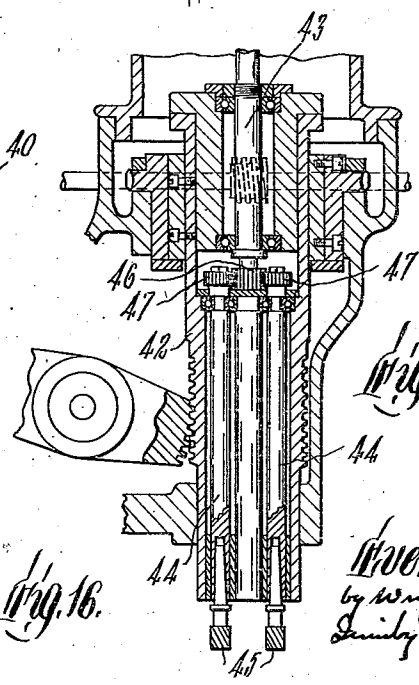


Fig. 17.

Inventor
Everard Stubbs
by Wright, Brown
Quinby & Macy Attys.

Patented July 30, 1940 2,209,483

UNITED STATES PATENT OFFICE

2,209,483

METHOD AND MEANS FOR FINISHING RECESSES

Everard Stubbs, Springfield, Vt., assignor to The Fellows Gear Shaper Company, Springfield, Vt., a corporation of Vermont

Application March 7, 1938, Serial No. 194,346

14 Claims. (Cl. 90—11)

The object of this invention is to enable a plurality of holes or other recesses to be finished in one operation to predetermined dimensions and with predetermined relationships between them. The recesses referred to may be holes in a piece of any character, open notches in the external or internal circumference of a plate or hub or a ring, splines, keyways, the tooth spaces of gear elements, and other formations of many kinds. The principles of the invention and some of the results which it is adapted to accomplish are explained in the following specification in connection with illustrative embodiments shown in the drawings.

In the drawings—

Fig. 1 is a sectional view of a work piece and a plurality of cutting tools showing their relationship in the operation of finishing a number of holes equally spaced from one another at equal distances from a common center;

Figs. 2–7 are plan views on a larger scale of the tools and work piece shown in Fig. 1, illustrating successive steps in the operation of finishing the holes to predetermined diameter;

Figs. 8, 9 and 10 are views similar to Figs. 3, 5 and 7 respectively, showing a variation of the same principle whereby holes of respectively different diameters are finished to predetermined diameters and with their predetermined spacing;

Fig. 11 is a diagrammatic view of mechanical means suitable for performing the method thus illustrated;

Figs. 12 and 13 are plan views of cooperating parts of a coupling which may be produced by this method;

Figs. 14, 15 and 16 are diagrammatic plan views illustrating the application of the method to produce internal gears, internal clutch members and recessed machine elements complemental to multi-splined shafts;

Fig. 17 is a sectional view of a tool assemblage adapted to perform the method described, illustrating the equivalency for this purpose of different types of tool.

Like reference characters designate the same parts wherever they occur in all the figures.

In the illustration of Figs. 1–7 it is assumed that a work piece W is to be produced with a plurality of holes of equal diameters spaced equally from one another and at equal distances from a common center *a*. The work piece here is shown as a circular disk, but it typifies any article in which any number of holes are to be produced at any prescribed distances from the center. The holes are first made, as by drilling or casting, of smaller than the prescribed finished size and with a more or less close approximation to their prescribed spacing. The rough cutting or formation of the piece is not a part of this invention. What I have sought and accomplished is to finish the roughly formed and spaced holes with greater truth and accuracy, and at the same time more economically, than has been possible heretofore.

In performing my method in one manner of procedure, I provide a plurality of planing cutters designated T^1, T^2, T^3, T^4 and T^5, having circular cutting edges at one end, of a diameter smaller than the roughed out holes, and tapered sufficiently to provide cutting clearance back from such edges, and secure them to a rotatable spindle **20** so that they protrude from one end of the spindle with their axes parallel to one another and to the axis of rotation of the spindle, and their centers are spaced apart and from the axis of the spindle equally to the prescribed center spacing of the holes to be finished. The work piece is mounted in or on a rotatable holder with the center *a* coaxial with the axis of rotation of the holder, and the holder and cutter spindle are relatively adjusted so that all the cutters may simultaneously enter corresponding holes in the work piece. This may require the axes of the spindle and work holder to be brought into alinement, or intersection at the location of the work piece, but not necessarily if the roughed out holes are considerably larger than the cutters. The rotational axes of the cutter and work holders may be either parallel or inclined, one relatively to the other, for producing parallel sided or tapered recesses, respectively.

Either the cutter spindle or the work holder is reciprocated in the direction of the spindle axis, and a lateral depth feed is produced between them. Thereby the cutters are caused to plane the holes in which they operate, at one side, as illustrated in Fig. 3. (It is understood of course that the length and location of the path of this relative reciprocation is such that the cutters will act throughout the entire length of the holes or of the portion thereof required to be finished.) The extent of depth feed is determined by the known diameter of the cutters and by the prescribed finished diameter of the holes, and is continued until the distance of offset between the axis *a* of the work holder and axis *b* of the cutter spindle (Figs. 3–7) is equal to half the difference between these diameters. In Figs. 2–6 the dotted circles or segments *c* in-

dicate the prescribed finished outlines of the holes.

The spindle and work holder are thereupon rotated simultaneously about their respective axes in the same direction at the same angular velocity. The centers *t* of the cutters then revolve in a path designated by the broken circle *d*, and the centers *h* of the holes revolve in the path designated by the broken circle *e*. It is assumed that the rotation is in the direction of the arrow shown in Figs. 3, 4, 5 and 6. When this simultaneous rotation has proceeded through 90°, the cutters and work arrive in the position shown in Fig. 4; after 180° of rotation they arrive in the position of Fig. 5; and after 270° they reach the position of Fig. 6. Fig. 7 shows them in starting position after completion of a revolution.

It is possible to perform the depth feeding and rotary cutting actions simultaneously instead of successively, but in that case the rotary action must continue throughout a complete revolution of cutters and work after the cutting has proceeded to full depth.

In order to produce accurately spaced holes with equal diameters, the tools must be accurately spaced and the diameters of the several tools must be identical; but the exact diameter of the tool is of no importance. This fact makes it possible to sharpen the tools by grinding off their ends any amount without impairing the accuracy of the results, provided only the tools have the same equality of diameter after sharpening. As the sides of the tools are tapered or relieved to provide cutting clearance, grinding away their ends reduces the diameter of their cutting edges. But when all of the tools have equal tapers and are ground equally, the equality of their diameters remains. All that is needed to finish holes of the same prescribed diameter after the cutters have been sharpened, is to increase the depth feed correspondingly.

By virtue of this method, work pieces of this character may be finished with extreme accuracy and very rapidly; and all pieces made by the same group of tools, or a duplicate group, are identical and interchangeable.

The invention is not limited to cases in which the holes must be of equal diameter and equal spacing from one another or from a common center. Figs. 8, 9 and 10 show how, in like manner, holes *k*, *l*, *m*, *n* and *o*, all different in diameter from one another, and unequally spaced from each other and from the center *a*, may be finished to their prescribed sizes and with their prescribed spacing by tools T^{11}, T^{12}, T^{13}, T^{14} and T^{15}. It will be obvious without further description that the same principles may be applied to obtain a multitude of specifically different results of the same general character.

The movements of reciprocation and rotation hereinbefore described may be produced in various ways by various kinds of machines. I do not limit the invention specifically in that respect, but include within the scope of my protection all suitable means for the purpose. However, the most satisfactory mode of performing the method described is to apply the cutters to the cutter spindle, and the work piece to the work spindle, of a Fellows gear shaping machine. Fig. 11 illustrates diagrammatically how this may be done. Here **21** represents the base of the machine in which is rotatably mounted a vertical work spindle **22** adapted to carry on its upper end an arbor, a chuck or a work table to which work pieces of various characters may be secured. The cutter spindle **20** is mounted rotatably and reciprocatively in a saddle **23** movable horizontally on ways **24** on a bed **25** which is slidably supported on the base and is adapted to be moved by a screw **26** and nut **27** so as to aline the cutter spindle with the work spindle and move it aside for placement and removal of work pieces. The spindle may be reciprocated and the saddle advanced for carrying out the depth feed, and moved slightly back and forth to back off the cutters on their noncutting strokes, by mechanisms such as those described in the patent of E. W. Miller 2,034,765, March 24, 1936. The spindles **20** and **22** are rotated simultaneously at equal angular velocity by worm and wheel gearings **28** and **29** respectively, driven from a motor **30** through a chain and sprocket drive **31**, shaft **32**, and gear trains adequately shown by dotted lines, which include a wide faced pinion **33**, an intermediate pinion **34** and a crown gear **35** for permitting movement of the bed **25** sufficient to clear the cutters from the work without breaking the continuity of the gear train between the two worm and wheel drives **28** and **29**. The machine thus described typifies a wide variety of machines and mechanical combinations suitable for the purpose.

The method is equally applicable for finish cutting open notches as well as completely surrounded holes; and Figs. 12 and 13 show cooperating parts of a machine coupling, both of which are producible by the same tool combination described in connection with Figs. 1–7. The externally notched member **36** is fitted to the interior cavity of the ring member **37** and is provided with notches **38** in its circumference of equal radius and identical spacing on centers to the notches **39** in the inner circumference of the ring member. When these members are assembled with their notches in registry, the half notches in each supplement those in the other to form complete circular holes in which balls may be placed to complete the coupling. The equality and accuracy of the center spacing and radius of the notches in both members so obtained, eliminates backlash with balls of correct diameters and enables the couplings to be quickly assembled.

In thus using cutters to finish open notches only a portion of the circuit of each cutter is used. For such work therefore it is not necessary that the outlines of the cutters make closed circuits nor that there be an open space between the cutters. Neither is it necessary that the cutting edges be parts of a continuous circular arc in each cutter. On the contrary the cutters may be provided as projecting parts of a solid cutter head, either integral with the head or separably attached to it, and the edges of the projecting cutters may have any outlines and may be made with appropriate dimensions and outlines to produce slots, keyways, etc. of any predetermined character. As illustrative of the infinite variety of such cutters usable in accordance with this invention, I have shown in Figs. 14, 15 and 16 an arrangement adapted to finish internal gears with involute teeth.

Here the cutters T^{21}, T^{22} and T^{23} are integral projections of a cutter head **40**, having involute cutting edges and, as will be readily understood without specific illustration, relieved faces to provide cutting clearance. Such cutters are adapted to finish the teeth of an internal gear **41**. Of course to make such a gear with equally spaced teeth, the cutter head must be provided with an equal number of cutters with the same angular spacing; but in order to simplify the drawings I

have shown here only three cutters spaced 90° apart around the center of the cutter head, and have indicated by the broken outlines of the cutter head and work piece the fact that intermediate cutters are provided in practical operation. But the principle is fully illustrated by the three cutters shown.

The gear blank, initially cut with slots narrower than the prescribed width (and possibly also less deep than the prescribed depth, although they may be deeper) of the finished tooth spaces, and the cutter head provided with suitably spaced cutters narrower than the slots, are mounted on the work and cutter spindles respectively of a machine such as that illustrated in Fig. 11, and centered nearly enough so that the cutters may enter the slots p, q, r, etc. The cutter head is then fed laterally a distance equal to half the amount by which the prescribed width of the tooth spaces exceeds the width of the cutters. The cutter T^{22}, which is assumed to be centered on the path of depth feed through the axis, then penetrates to full depth in the slot q, and would deepen the slot if the latter had not been initially cut to an excess depth. But preferably at least the outer corners of that cutter come into bearing on the opposite sides of the slot. At the same time the cutter T^{21} forms the side p' of the slot p and the cutter T^{23} forms the side r' of slot r. Intermediate cutters cut partly laterally and partly to greater depth in the slots occupied by them, in greater or less degree depending on the angularity of their radial center lines to the direction of feed.

The cutter head and work piece are then rotated in the same direction at the same angular velocity about their respective offset axes a and b. A point, as t, selected within the area embraced by the sides of the cutter T^{21}, travels in the path d, and a point h within the slot p, (coincident with the point t when the axes a and b are alined), travels in the path e, during the rotary action. Corresponding points in each of the other cutters and slots travel in the same paths.

During the first quadrant of rotation, the cutter T^{21} increases the radial depth of its cut and finishes the side p' of slot p, while separating from that portion of the surface which was cut during the depth feed, until it reaches the position of the cutter T^{22} shown in Fig. 15. At the same time the cutter T^{22} passes to the position of T^{23}, withdrawing partially from the slot q and cutting away the side q' of this slot to its final form and outline, which is similar to that of the side p^2 of slot p shown in Fig. 16.

After rotating through 180° the three cutters here represented occupy positions as shown in Fig. 16. The cutter T^{23}, having been idle during its first 90° of rotation, has cut away the side r^2 of its slot r to the likeness of the face p' in Fig. 15 during its second 90°; the cutter T^{22} has traveled idly through its second quadrant; and the cutter T^{21} has cut the side p^2 of the slot p to finished form and dimensions.

In the third 90° of revolution the cutter T^{21} is idle, the cutter T^{22} enters the side q^2 of slot q, and the cutter T^{23} finishes the side r^2 to final depth and form. In traversing the fourth quadrant, the cutter T^{22} finishes the side q^2 to final depth and form, and the cutter T^{23} similarly finishes the side r'. Each cutter goes through the same cycle of cutting first one side and then the other of a slot to full width, and of deepening the sides of the slots radially, but different cutters perform the steps of the cycle in different sequences. Where the sides of the cutters are of involute curvature, as here shown, they generate involute tooth curves in the work piece. The outer corners of the cutters generate fillets of circular curvature with radii equal to the offset between the axes. If rotation is carried on simultaneously with the depth feed, as it may be, the ultimate result is the same, but without the sharp demarcation between the effects due to depth feeding and those due to rotation.

By an obvious reversal, cutter heads with internal cutters can be used to generate external gear teeth, or other projections on work pieces. It will be obvious that any numbers and shapes of slots and intermediate lands within the space limitations of the apparatus used may be produced externally or internally in many kinds of work pieces.

Where the holes or recesses to be finished are of circular outline, rotating tools such as milling cutters or grinding wheels may be used instead of planing cutters. Fig. 17 shows an operative arrangement of such rotatable cutters for performing such work as that shown in Figs. 2–7, 12 and 13. A quill 42 which is rotatable and reciprocable like the cutter spindle of Fig. 11 contains a centrally mounted rotatable shaft 43 and tool spindles 44 in circular series around the shaft. The milling cutters 45, or equivalent grinding wheels, are fixed in the shafts 44, protruding similarly to the cutters T^1, etc. from the spindle 20 in the arrangement of Figs. 1 and 11. Rotation imparted at the desired speed to the central shaft 41, by a motor or driving train of any suitable character, is transmitted to the spindles by intermeshing gears 46 and 47 on the shaft and spindles respectively. In this case the reciprocative movement of the quill is used only to advance the tools axially into the work and withdraw them. During the depth feeding and rotational generative movements the quill is not displaced axially.

A common principle resides in all these illustrated embodiments of the invention, and equivalent embodiments, namely, that a plurality of cutters are simultaneously put in operation on the work, and are revolved about a common axis while the work is rotated at the same angular velocity about another axis parallel to and offset from the first axis when holes or recesses of uniform width or depth from end to end are to be made, or an inclined axis in cases where the holes or recesses are to be tapered. When the axes are parallel, the revoluble component of motion of the tools is in planes parallel to the work piece; and when tapered recesses are being produced, the corresponding planes are inclined to the work piece. The term "cutter" in this specification and in the following claims is intended to include tools of the type commonly considered as abrasive or abfading tools, as well as those which have distinct cutting edges. That is, grinding wheels, laps and the like are embraced within this definition.

Practical means for effecting the revolution of work and cutters about non-parallel axes, as, for instance, by inclining either the cutter spindle or the work spindle from the position shown in Fig. 11, without inclining the other, or by inclining both, but in different directions or at relatively different degrees, will be obvious to all skilled in the art without specific illustration. So also it will be understood that the lateral com-

ponent of the taper-cutting path may be given by operating the depth feed mechanism reciprocatively and continuously during the working and return strokes of the cutters, in those cases where the cutting is performed by relative reciprocation between the work holder and the cutters in the direction of the cutter spindle axis.

What I claim and desire to secure by Letters Patent is:

1. The method of simultaneously finishing a plurality of recesses to prescribed dimensions in a work piece, which consists in providing an equal number of cutting tools of smaller transverse dimensions than the prescribed finished dimensions of such recesses, locating the cutting tools in recesses of smaller than finished dimensions in the work, revolving the tools and rotating the work simultaneously at equal angular velocity about different axes correspondingly related to the tools and recesses, respectively, and spaced apart a distance less than the orbital radius of any tool, and causing said tools at the same time to perform a cutting action.

2. The method of producing recesses of prescribed dimensions, and with a prescribed spacing between corresponding points in each, in a work piece, which consists in locating cutters with a spacing between corresponding points equal to such prescribed spacing, in operative proximity to the work, revolving the cutters simultaneously about a common axis distant from all of the cutters, simultaneously rotating the work piece about another axis offset from the first axis by a distance substantially equal to half the difference between the prescribed finished widths of the recesses and the widths of the respectively corresponding cutters, and at the same time producing a relative cutting movement between the cutters and work.

3. The method of enlarging to predetermined size and establishing a predetermined spacing between previously formed recesses in a work piece, which consists in providing a plurality of tools of smaller dimensions than the said recesses and with the prescribed spacing between them, locating said tools each in one of the recesses, relatively feeding the tools and work piece laterally in one direction while causing the tools to perform a cutting action, and simultaneously revolving the work piece and tools at equal angular velocities about different axes separated from one another by a distance equal to half the difference in width between the prescribed finished dimensions of the recesses and the corresponding dimensions of the respective tools, while continuing the cutting action of the tools.

4. The method of enlarging previously formed holes in a work piece and establishing the centers of such holes at predetermined distances from each other and from a common reference point, which consists in providing a plurality of circular cutting tools with their centers spaced apart from each other and from a common reference point equally to the corresponding prescribed spacing of the holes, approximately alining the reference points of the work piece and collection of tools and of the centers of the holes and tools so that each tool may enter one of the holes, effecting relative cutting and depth feeding movements between the tools and work piece until each tool has penetrated the work laterally to a distance equal to half the difference between the finished diameters of the holes and the diameters of the respective tools, and simultaneously revolving the work piece and tools in parallel planes and at equal angular velocities around their respective reference points while continuing the relative cutting action.

5. The method of enlarging to prescribed dimensions, and spacing to prescribed center distances, a plurality of external recesses in a work piece, which consists in locating cutting tools with a prescribed center spacing between them in cutting relationship to the several recesses, effecting relative cutting movements between said tool and work piece, effecting a relative depth feed between the tools and work piece, and effecting simultaneous revolution between the collection of tools and work piece about parallel axes offset from each other a distance less than the orbital radius of the tool nearest the axis of revolution of said collection, and with equal angular velocities.

6. The method of enlarging internal recesses within an annular work piece and establishing such recesses at given distances from each other and from the center of the work piece, which consists in providing a number of tools equal to the number of such recesses, of dimensions small enough to enter the recesses and spaced apart from each other and from a common center equal to the prescribed spacing of the finished recesses, causing relative cutting movements between the cutter and work piece and relatively locating the center of the work piece and the common center of the cutters on parallel lines laterally spaced apart by a distance equal to half the difference between the prescribed finished width of the spaces and the width of the cutters, and simultaneously revolving the work piece and cutters around such parallel lines at equal angular velocities.

7. The method of enlarging recesses in a work piece to prescribed finished dimensions, which consists in providing a group of tools equal in number and of like spacing and arrangement to the recesses, but of less width than the recesses, locating all of said tools at the same time in cutting relationship to the boundaries of the respective recesses, revolving the group of tools about an axis distant from all of the tools, simultaneously rotating the work piece in the same direction and at the same angular velocity as said group of tools about an axis having the same relationship to the recesses as the axis of said group has to the several tools, said axes being offset, one with respect to the other, from the relationship occupied when the tools are centered with respect to the orifices of the respective recesses, by a distance substantially equal to half the difference between the widths of the recesses and the widths of the corresponding tools, and effecting a relative cutting action between the tools and work piece of a character to remove stock from the walls of the recesses.

8. The method of simultaneously enlarging a plurality of tapered recesses in a work piece, which consists in providing cutting tools equal in number to the recesses with a spacing from one another and from a common reference point corresponding to the spacing of the recesses from each other and from a reference point in the work piece, which tools are of less width than the respectively corresponding recesses and are all in equal measure narrower than the prescribed finished widths of such recesses, effecting relative cutting movements between the tools and work piece, revolving the collection of tools and rotating the work piece, in the same direction with equal angular velocities, around axes inclined to

one another, of which the tool collection axis passes through the first-named reference point, and the work piece axis passes through the second named reference point, and establishing a separation between the axes which, in the plane perpendicular to the work piece axis containing the smaller orifices of the recesses is substantially equal to half the difference between the prescribed finished widths of the several recesses and the widths of the corresponding tools.

9. The method of enlarging a recess in a work piece which comprises providing a cutting tool of a width less than that of the recess to be enlarged, locating the tool in operative proximity to the boundaries of the recess, revolving the tool and rotating the work piece in the same direction and at equal angular velocities, about axes equally distant from corresponding points within the outlines of the tool and the recess, respectively, and displaced from one another by a distance substantially equal to half the difference between the prescribed enlarged width of the recess and the width of the tool, and effecting a relative cutting action between the tool and work piece.

10. An apparatus for performing the foregoing method which comprises a plurality of cutters having their respective cutting edges disposed in closed circuits, a rotatable cutter holder having means for mounting said cutters spaced apart from one another and from the axis of the holder, a work holder rotatable about an axis other than that of the cutter holder, means for adjusting one of said holders relatively to the other to increase and diminish the lateral distance between their respective axes, means for effecting relative cutting movements between the cutters and work holder, and means for simultaneously rotating said holders about their respective axes.

11. An apparatus for performing the foregoing method comprising a plurality of cutters having their respective cutting edges disposed in closed circuits, a rotatable cutter holder having means for mounting said cutters spaced apart from one another and from the axis of the holder, a work holder rotatable about an axis inclined to that of the cutter holder, means for adjusting one of said holders relatively to the other in a path transverse to both axes, means for simultaneously rotating both holders about their respective axes at equal angular velocities, and means for effecting relative cutting movements between the cutters and work holder.

12. An apparatus for simultaneously enlarging a plurality of recesses in a work piece, which comprises a rotatable cutter carrier, a plurality of cutters, each having a circular cutting edge substantially in a plane perpendicular to the axis of said carrier, mounted on the carrier in locations eccentric to said axis, a work holder mounted with provision for independent rotation about a different axis, means for effecting a relative adjustment between said cutter carrier and work holder to bring their respective axes substantially into coincidence and to separate one from the other in various measure, mechanism for rotating said carrier and holder about their respective axes in the same direction at equal angular velocities, and means for effecting relative cutting movements between the cutters and work holder.

13. An apparatus for simultaneously enlarging a plurality of recesses in a work piece, which comprises a rotatable cutter carrier, a plurality of cutters having their cutting edges disposed in a circular closed circuit and being mounted rotatably on the carrier in locations spaced away from the axis of the carrier and from each other, a work holder mounted with provision for independent rotation about a different axis from that of the carrier, means for effecting a relative adjustment between said cutter carrier and work holder to place their respective axes at various distances, one from the other, mechanism for rotating said carrier and holder about their respective axes in the same direction at equal angular velocities, and means for rotating the cutters about axes concentric with their respective cutting-edge circuits whereby to accomplish a cutting effect.

14. An apparatus for simultaneously enlarging a plurality of recesses in a work piece, which comprises a rotatable cutter carrier, a plurality of cutters rotatably mounted on the carrier to turn about axes spaced apart from the axis of the carrier and from each other, a work holder mounted with provision for independent rotation about a different axis from that of the carrier, means for effecting a relative adjustment between said cutter carrier and work holder to place their respective axes at various distances, one from the other, mechanism for rotating said carrier and holder about their respective axes in the same direction at equal angular velocities, and means for rotating the cutters about their individual axes to accomplish a cutting effect.

EVERARD STUBBS.