July 2, 1940. J. M. CHRISTMAN 2,206,449

APPARATUS FOR FINISHING GEARS

Filed Dec. 6, 1934 5 Sheets-Sheet 1

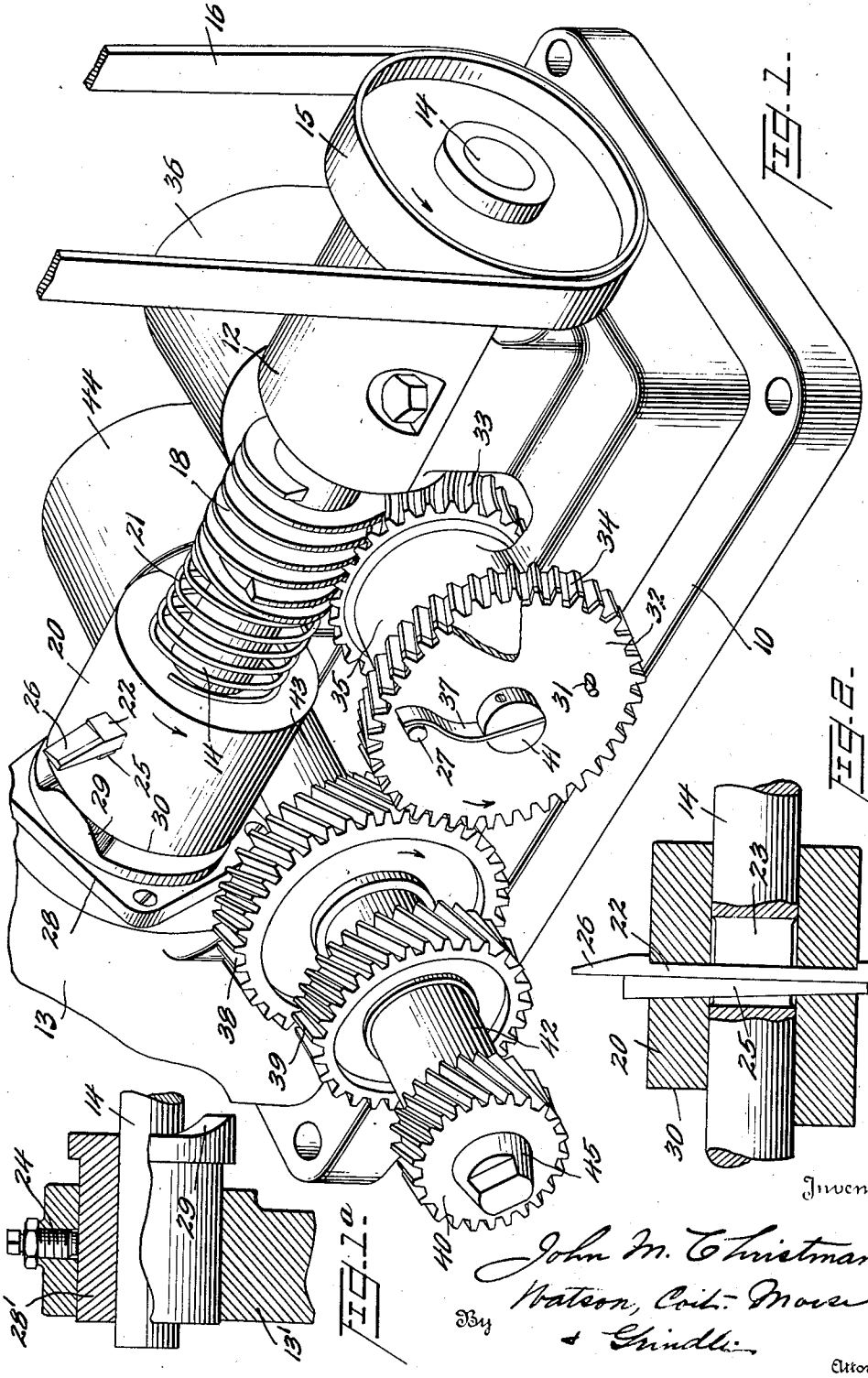


FIG. 1.

FIG. 2.

FIG. 1a.

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FIG. 5.

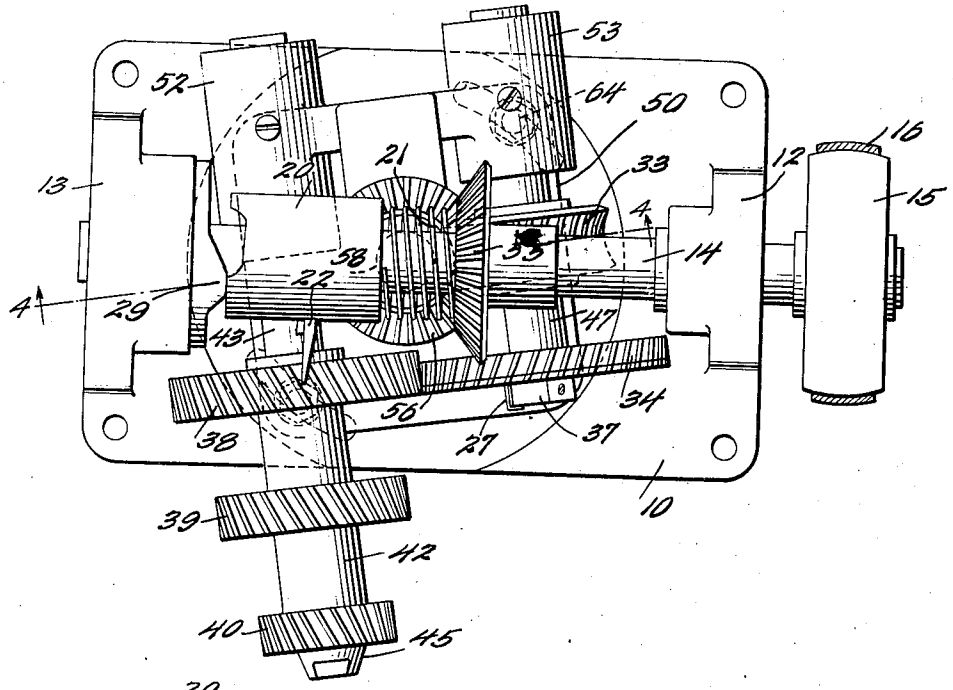
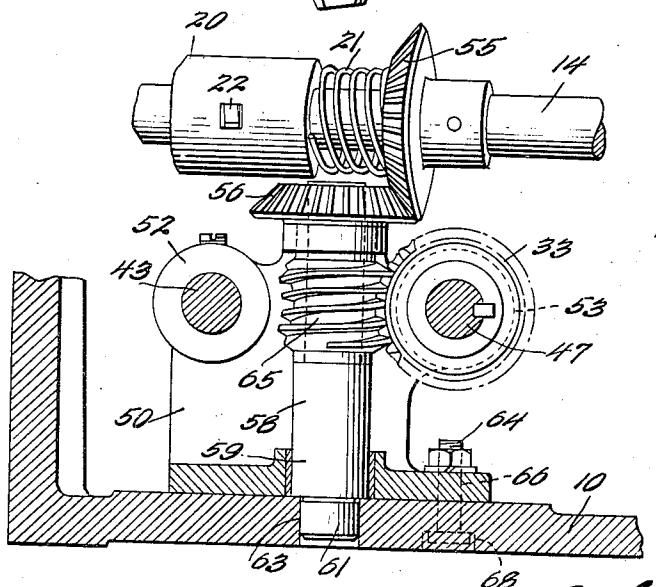


FIG. 4.



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APPARATUS FOR FINISHING GEARS

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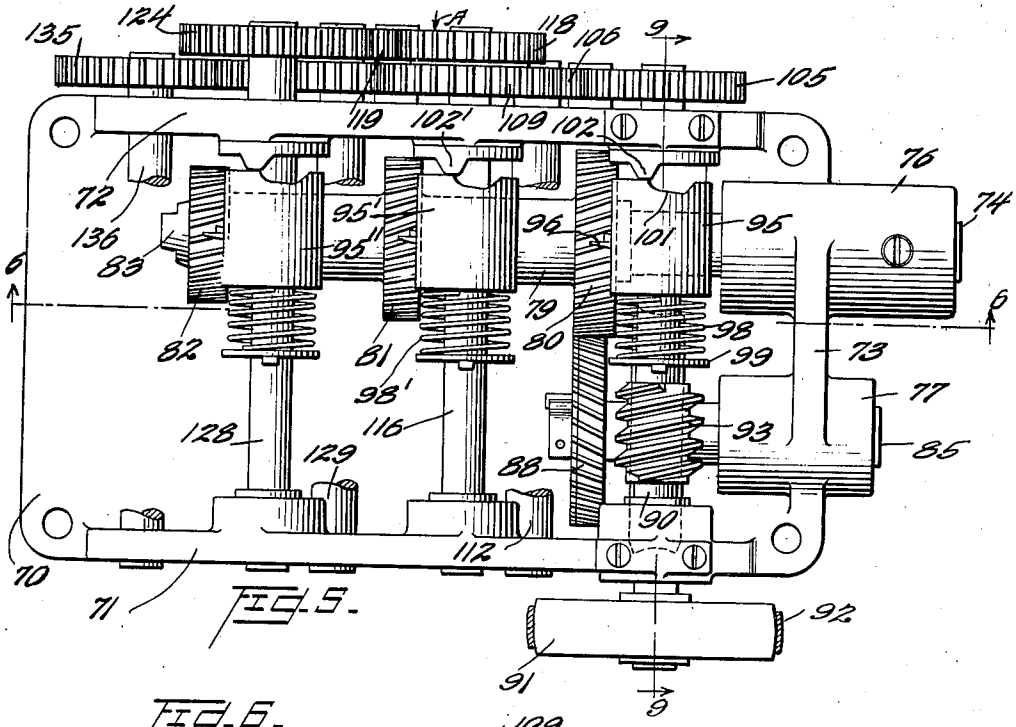


FIG. 5.

FIG. 6.

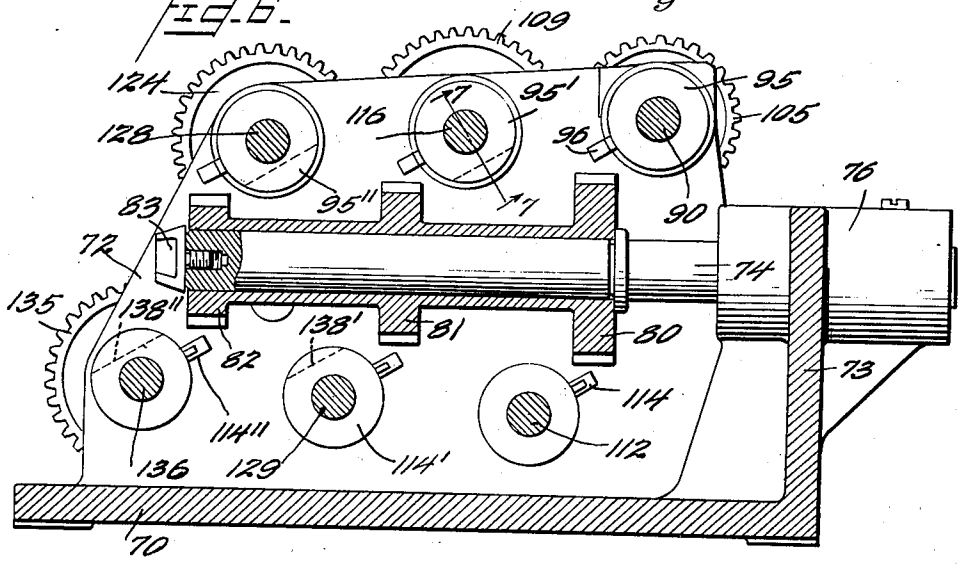
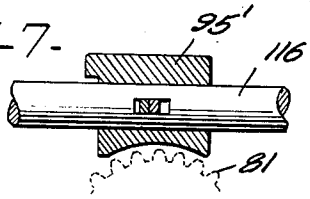


FIG. 7.



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FIG. 8.

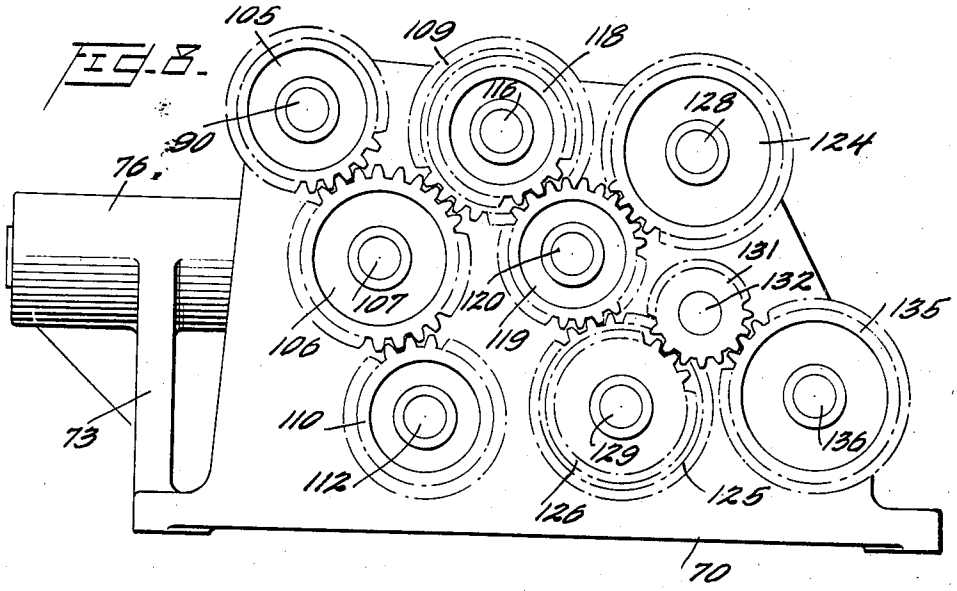


FIG. 9.

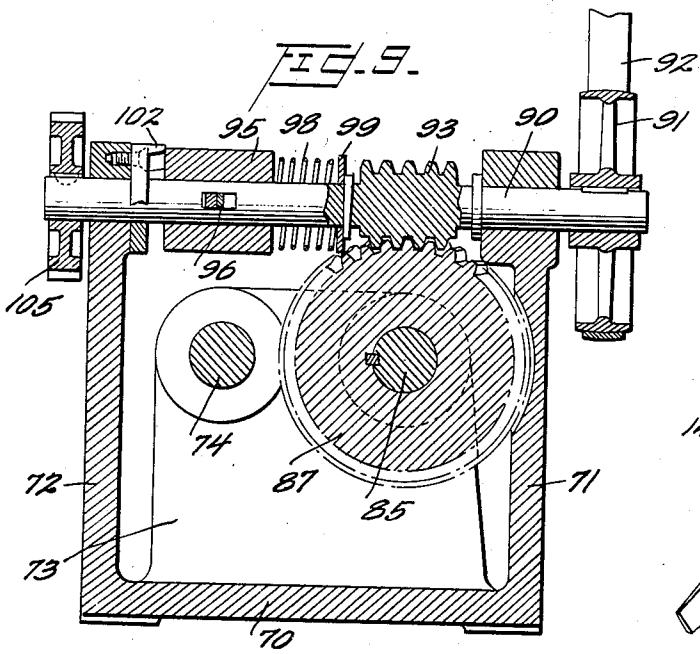
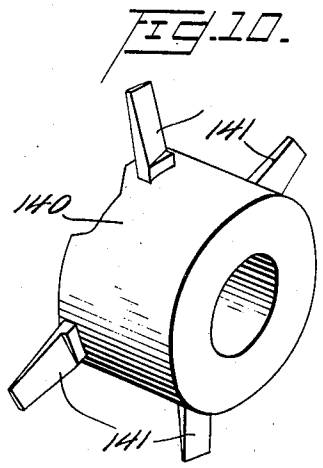


FIG. 10.



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FIG. 11.

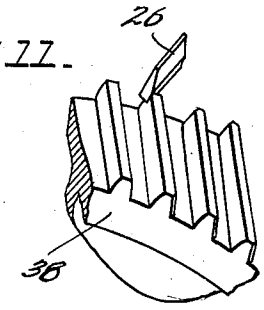


FIG. 12.

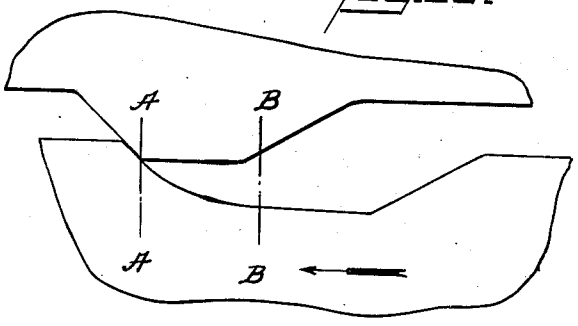


FIG. 13.

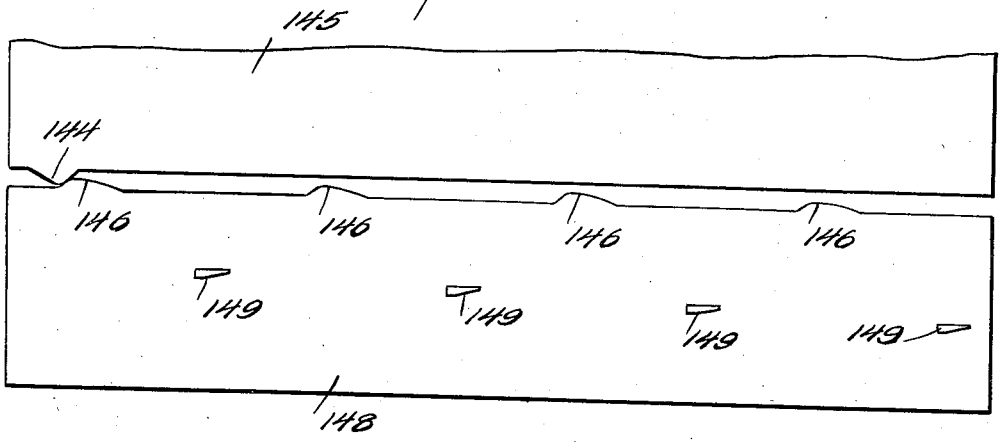
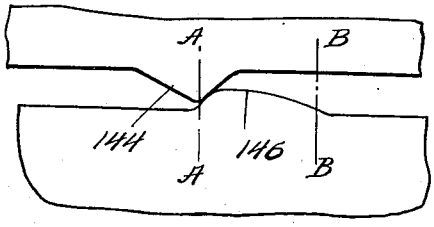


FIG. 14.



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Patented July 2, 1940 2,206,449

UNITED STATES PATENT OFFICE

2,206,449

APPARATUS FOR FINISHING GEARS

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Application December 6, 1934, Serial No. 756,349

17 Claims. (Cl. 90—1)

This invention relates to a gear chamfering or burr removing machine and has for its object the provision of a machine of this character which is simple to construct and operate and which will rapidly and efficiently chamfer the edges of gear teeth or remove the burrs formed during manufacture at the intersection of the working surfaces of the teeth with the end faces thereof.

This operation, commonly done by hand by means of a file, not only serves to prevent the breaking off during use of the gears of small particles of metal, which is obviously highly objectionable in the event the gears are used in an automobile transmission or other closed lubricated housing, but in the case of gears which are axially shiftable into and out of mesh, such as starter gears or gears employed in change speed transmissions, the meshing of the gears is facilitated by the provision of cooperating chamfered or beveled edges.

It is a feature of the invention that the machine may be readily adapted to effect the chamfering of the edges of the gear teeth either by the performance of a single cutting operation on each tooth or by the application of successive cuts on each tooth, the former being desirable where rapid treatment of the gears is desired and where a light cut or chamfer is sufficient, and the latter being preferable in the event very pronounced chamfering is necessary, for instance as in the case of starter gears or the like.

It is a more specific object of the invention to provide a gear chamfering machine employing a cutter having one or more tools or cutting edges which are moved through a path intersecting the edges of the gear teeth together with means for supporting and simultaneously rotating the gear to present successive teeth to the action of the cutter. In the preferred form of the invention the cutter is supported for rotation and for axial movement on an axis generally parallel with the plane of the gear undergoing treatment, and the gear is in turn rotated in timed relation with the rotational and axial movement of the cutter, the axial movement imparted to the cutter being so calculated as to accommodate the path of movement of the cutting tool to the slope of the working face of the tooth. In the event the rotation of the gear is continuous, the axial movement of the cutter is also calculated so as to compensate for rotational movement of the gear during actual engagement of the gear and cutter.

It is a further feature of the invention that the inclination of the cutting tool with respect to the plane of the gear may be readily altered so as to vary the angle of the cut without disturbing the timed relationship of movement of the gear and cutter.

It is a further object of the invention to provide a machine for chamfering the edges of gear teeth which will operate simultaneously on the several units of a gear cluster, the construction being preferably such that regardless of the relative sizes of the gears in the cluster the operation of chamfering on all the units may be begun and completed simultaneously and during one complete rotation of the gear cluster. Still further the machine may be so constructed as to operate simultaneously on the opposite ends of the teeth of either a single gear or a plurality of gears.

Further objects and features of the invention will be apparent from the following description taken in connection with the accompanying drawings, in which

Figure 1 is a perspective view of a gear chamfering machine embodying the principles of the present invention;

Figure 1*a* is a fragmentary sectional view illustrating a slightly modified form of a detail shown in Figure 1;

Figure 2 is a sectional view of the cutter illustrated in Figure 1;

Figure 3 is a view in plan illustrating a modification of the arrangement shown in Figure 1;

Figure 4 is a sectional view taken substantially on the line 4—4 of Figure 3;

Figure 5 is a view in plan illustrating a further modification of the machine shown in Figure 1;

Figure 6 is a sectional view taken substantially on the line 6—6 of Figure 5;

Figure 7 is a fragmentary sectional view taken substantially on the line 7—7 of Figure 6;

Figure 8 is an elevation of the structure shown in Figure 5 viewed in the direction of the arrow A;

Figure 9 is a section on the line 9—9 of Figure 5;

Figure 10 is a perspective view of a modified form of cutter;

Figure 11 illustrates the manner in which engagement between a cutting tool in the end of a gear tooth may take place; and

Figures 12, 13, and 14 are developments of cams suitable for imparting the necessary axial movement to a cutter or cutters during operation of the machine.

For convenience in describing the invention, reference is made to the several embodiments thereof illustrated in the accompanying drawings and specific language is employed. It will nevertheless be understood that no limitation of the

scope of the invention is thereby intended but that various further modifications and alterations are contemplated such as would occur to one skilled in the art to which the invention relates.

Referring first to Figure 1 of the drawings, it will be observed that the machine disclosed therein comprises a base 10 provided adjacent either end thereof with bearing blocks 12 and 13 in which a shaft 14 is journaled for rotation, a pulley 15 driven by a belt 16 being secured to one end of the shaft. Secured to or formed on the shaft 14 is a worm 18 and a tool holder 20 is supported on the shaft 14 for rotation therewith and for axial movement thereon, a coil spring 21 interposed under compression between the worm 18 and the holder 20 being preferably provided to urge the holder 20 in one direction on the shaft or to the left in Figure 1.

The holder 20 carries one or more cutting tools which may be of the double ended type as indicated at 22 in Figure 2, tool 22 extending through the holder 20 and through a slot 23 in the shaft 14, being retained in position within the holder by means of a wedge 25. It will be observed that with this construction the tool 22 and the wedge 25 constitute in effect key means permitting bodily displacement of the holder 20 on the shaft while constraining the shaft and holder to rotate together. Since the tool 22 projects at each end from the holder, two cutting portions 26 are afforded and thus two cuts will be made for each rotation of the shaft 14. For convenience the holder 20 and cutting tool 22 are referred to hereinafter as a cutter, it being obvious from the following description that the construction of this cutter may vary materially from the form illustrated in the drawings.

Cooperating cam surfaces are preferably formed on a stationary portion of the machine and on the holder 20 to effect reciprocation of the holder on the shaft 14 as the latter is rotated. For instance a cam member 28 may be secured to the bearing block 13 and may surround the shaft 14, the cam member 28 being provided with a radial cam face 29 cooperating with the corresponding cam face formed on one end 30 of the holder 20. The nature of the cooperating cam surfaces will be more fully pointed out hereinafter.

The worm gear 33 and the spur gear 34, secured for unitary rotation on a shaft which may be journaled on the base 10 in any suitable manner, for instance in bearing blocks 35 and 36, are arranged to drive a gear 38, to be chamfered, from the shaft 14, the worm gear 33 meshing with the worm 18 and the spur gear 34 meshing with the gear 38. Preferably the gear 34 is of the conventional type designed to eliminate backlash, having a separately rotatable portion 32 which is permitted limited movement with respect to the body of the gear by means of the pin and slot connection 31, being urged in one direction by a spring 37 carried by a member 41 secured to the body of the gear, this spring in turn engaging a pin 27 projecting from the outer face of the portion 32. The function and mode of operation of this type of gear is well understood.

The gear 38 may comprise a single unit or may be one of a cluster of gears including the gears 39 and 40 as shown in the drawings, all three of these gears being formed on or secured to a sleeve 42. The sleeve 42 may be keyed for rotation on a shaft 43 journaled in a bearing block 44 formed on the base 10 of the machine and may be secured in position on the shaft 43 by means of a nut 45.

It will be observed that as the shaft 14 is rotated, the cutter will be moved transversely of the plane of member 28, the cutting portion 26 of the cutting tool engaging the edge of a tooth of the gear 38 on each rotation of the shaft 14, preferably in the manner indicated more particularly in Figure 11 of the drawings. By reason of the geared connection between the shaft 14 and the gear 38, the latter will also be continuously rotated, the extent of rotation of the gear 38 being determined by the ratio of the connecting gearing and being such that in this embodiment of the invention succeeding teeth are engaged and cut by the tool. In other words, if the cutter is provided with two tools, for instance the double ended tool 22 shown in Figure 2, the gear 38 will be advanced two teeth during each rotation of the shaft 14 and the cutter carried thereby. The direction of rotation of the several elements of the machine is indicated by the arrows in Figure 1.

Since the working faces of the teeth on the gear 38 are curved and since the gear 38 is rotated through a small angle during engagement of the cutter with a tooth, it is necessary to effect relative displacement of the gear 38 and the cutter during engagement. While the gear 38 might be displaced generally in the plane thereof for this purpose, it is more convenient to employ the construction shown in the drawings and to reciprocate the cutter on the supporting shaft 14 by means of the cooperating cam surfaces hereinbefore referred to. The nature of these cam surfaces will be more clearly understood from an inspection of Figure 12 of the drawings showing a development thereof. In this figure that portion of the cam surface on the holder 20 lying between the lines A—A and B—B is in engagement with the cam element 28 during engagement of the cutting tool with a tooth of the gear 38. It will thus be observed that during this engagement the cutting tool 22 is moving downwardly by reason of the rotation of the shaft 14 and is at the same time displaced to the left in Figure 1 in accordance with the contour of the cam surfaces illustrated in Figure 12. This displacement of the cutter to the left is necessitated by the curvature of the working surface of the tooth on which the cutter is operating, the cutter of Figure 1 being arranged to engage the trailing edge rather than the leading edge of each tooth. During the period of engagement between cutter and tooth there is also a slight rotational movement of the gear 38 in the direction of the arrow or away from the cutting tool, but the extent of rotation of the gear is slight and is fully compensated for by the correct shaping of the cam surfaces shown in Figure 12. If desired, rotation of gear 38 may be suspended during actual cutting by employment of a Geneva movement or the like, but it will be appreciated that the arrangement shown in the drawings is simpler and more efficient.

It will be observed that the gear 38 shown in Figure 1 is of the helical type and the chamfering is thus preferably effected on that edge of the tooth which affords the more acute angle and which is therefore more subject to burring and chipping during formation and use. It will nevertheless be understood that the machine illustrated may be employed to chamfer the teeth of spur gears of the straight tooth type or of bevel

gears, and may be constructed to accommodate various tooth forms such as cycloidal, involute, or other shapes of working surface, it being only necessary to vary the nature of the cam surfaces to obtain the required axial displacement of the cutter during the chamfering operation.

While the gear 38 shown in Figure 1 of the drawings employs teeth having a left-hand helix, gears having teeth of right-hand helices may also be readily chamfered, chamfering being then preferably effected on the leading rather than the trailing edge of the tooth. In this case the cam surfaces will correspond more nearly to those developed in Figure 14, the cutter being moved to the right in Figure 1 of the drawings, in other words in the direction of rotation of the gear 38, during actual engagement of the cutter and tooth.

It may be found desirable to effect some slight adjustment of the cooperating cam surfaces after the machine is set up. An arrangement permitting such adjustment is illustrated in Figure 1*a* in which the stationary cam element 28' is supported within the bearing block 13' for rotation about the axis of the shaft 14, being retained in any desired position of adjustment by means of the set screw 24.

Figures 3 and 4 of the drawings illustrate a construction which is generally similar to that shown in Figure 1 with the exception that provision is made for effecting relative angular displacement between the cutter and the gear being chamfered about an axis generally parallel to the plane of the gear, similar reference characters being employed to indicate similar parts of the machine. Thus the gear 38 and the shaft 43 on which the gear is supported may be mounted for rotation in a carrier 50, the worm gear 33, the gear 34, and the shaft 47 to which the latter are secured being likewise supported in this carrier. Thus the shaft 43 may be journaled in a bearing boss 52 and the shaft 47 may be journaled in a similar boss 53, these bosses being preferably formed on the carrier 50.

The shaft 14 carries a bevel gear 55 which is secured to the shaft and which meshes with a second bevel gear 56, the latter being secured to a shaft 58 which is journaled as at 59 in the lower portion of the carrier 50, the shaft 58 having a reduced portion 61 extending within an aperture 63 in the base 10 of the machine and affording a pivotal connection between the carrier 50 and the base. Formed on or secured to the shaft 58 is a worm 65, the latter meshing with the worm gear 33 so that the gear 38 is rotated in timed relation with the shaft 14 as hereinbefore described in connection with the embodiment of the invention shown in Figure 1. A bolt 64 fitting within an aperture 66 in the carrier 50 and received within a generally arcuate slot 68 in the base 10 is employed to secure the carrier 50 in any position to which it may be adjusted about the axis of the shaft 58.

It will be observed that the gearing including the beveled gears 55 and 56 constitutes what is commonly referred to as pivoted gearing, permitting swinging movement of the carrier on the base without interfering with the driving connection between the shaft 14 and the gear 38. By effecting such pivotal displacement of the carrier 50, the angle at which the cutting tool 22 is presented to the gear 38 may obviously be altered with the result that the angle of cut may be varied. It is also clear that the depth of cut may be varied in either of the forms of the invention hereinbefore described by suitable change in the nature of the cooperating cam surfaces shown in Figure 12 or, in the form of the invention shown in Figure 1*a*, by displacement of the cam element 28' to the right or to the left to a slight extent.

Dealing now with the form of the invention shown in Figures 5 to 9 inclusive, it will be observed that the machine therein illustrated is so constructed as to simultaneously chamfer the edges at opposite ends of the teeth of a single gear or of the several gear units of a gear cluster. Thus the base 70 of the machine is provided with upstanding bearing flanges 71 and 72 at opposite sides thereof, and a flange 73 at one end, the latter serving as a support for bearing bosses 76 and 77. Journaled within the bearing boss 76 is a shaft 74 on which may be secured a sleeve 79 of the gear cluster comprising the gears 80, 81, and 82, a nut 83 being employed for this purpose. Journaled within the boss 77 is a shaft 85 on which is secured a worm gear 87 and a spur gear 88, the latter being preferably of the backlash take-up type hereinbefore described. Journaled in the bearing flanges 71 and 72 is a shaft 90 on which is secured a driving pulley 91 operated by a belt 92, the shaft 90 having formed thereon or secured thereto a worm 93 meshing with the worm gear 87. A cutter indicated at 95 and employing one or more cutting tools 96 is mounted on the shaft 90 for rotation therewith and for axial movement with respect thereto. A coil spring 98 interposed between a collar 99 and the cutter 95 urges the latter to the left in Figure 9, the cutter 95 being provided with a radial cam surface 101 cooperating with a radial cam 102 secured to the flange 72. The gear 88 meshes with the gear 80 which is one unit of the gear cluster to be chamfered. It will be observed that the construction thus far described is identical with that illustrated in Figure 1 of the drawings and functions in a similar manner to chamfer the trailing edges of the teeth of the gear 80.

A spur gear 105 is secured to one end of the shaft 90, this gear constituting the first of a train of gears, all of which are shown in Figure 8 of the drawings. Thus gear 105 meshes with an idler gear 106 mounted on a shaft 107 journaled in the flange 72, the idler gear 106 meshing in turn with the gears 109 and 110. Gear 110 is secured to a shaft 112, journaled in flanges 71 and 72, on which is mounted for axial reciprocation on and for rotation with the shaft a cutter indicated at 114. This cutter is provided with one or more cutting tools, axial reciprocation of the cutter in the proper timed relation being effected by the cooperation of cam surfaces on the cutter and on a suitable cam element surrounding the shaft and secured to the inner face of the flange 72.

The gear 109 is secured to a shaft 116 on which is mounted a cutter 95' cooperating with the gear 81, the cutter 95' being rotatable with the shaft 116 and being reciprocable thereon by the cooperation of cam surfaces formed on the cutter and on a cam element 102' secured to the flange 72 of the machine frame. The cooperating cam surfaces are maintained in contact by a spring 98', the construction and mode of operation of the cutter 95' being similar to that of the cutter 95.

Secured to the shaft 116 is a gear 118 which meshes with an idler gear 119, the latter being mounted on a shaft 120 supported in the flange

72 of the machine frame, the idler gear 119 meshing in turn with a gear 124 and a gear 125. The gears 124 and 125 are secured respectively to shafts 128 and 129, the shaft 128 being provided with a cutter 95'' and the shaft 129 being provided with a cutter 114', these cutters being constructed and operating in the manner hereinbefore described. A gear 126 secured to shaft 129 meshes with an idler gear 131 secured to a shaft 132 journaled in the flange 72 of the machine frame, and the idler gear 131 meshes in turn with a gear 135 secured to a shaft 136 journaled in the flanges 71 and 72. Shaft 136 is provided with a cutter 114'' which is constructed and arranged to operate in the manner of the remaining cutters of the series. The cutters 114' and 114'' are provided with recessed portions 138' and 138'' respectively, whereby when these cutters are rotated to the proper positions, as indicated in Figure 7, the gear cluster to be chamfered may be slid longitudinally of the shaft 74 for application thereto or removal therefrom.

As is clearly shown in Figure 6 of the drawings, each of the cutters 95, 95', and 95'' are positioned to chamfer the trailing edges at one end of the teeth of the gears 80, 81, and 82 respectively, and each of the cutters 114, 114', and 114'' is arranged to chamfer the leading edges at the opposite ends of the teeth of the gears 80, 81, and 82 respectively, it being observed that in this manner chamfering of all of the acute edges of of all of the gears of the cluster may be effected simultaneously. The ratio of the gearing connecting these cutters and shown in Figure 8 of the drawings is preferably such that the chamfering of the gears may be begun and completed at the same time, for instance after one complete rotation of the gear cluster. Obviously the cutters which are simultaneously operating on any one of the gear units should be rotated at the same speed and will be reciprocated axially during the cutting operation in accordance with the principles hereinbefore outlined, but owing to the different sizes of the gear units in the gear cluster illustrated in the drawings, the cutters operating on the different gear units must necessarily be driven at different speeds in order that the proper timing may be established.

In Figure 10 of the drawings is shown a cutter 140 provided with four cutting tools 141 which are angularly displaced about the circumference of the cutter, the successive tools being also slightly displaced axially of the cutter to an extent corresponding generally to the angular displacement of the gear to be chamfered during the periods intervening between actual cutting engagement of the cutter and gear. In other words, the arrangement is such that the four cutting tools will be brought successively into engagement with a single tooth, each tool being positioned so as to effect a cut of slightly greater depth than that effected by the preceding tool. This construction is found to be particularly useful where a very deep chamfer is desired, for instance in the case of starter gears or the like. Obviously the number of cutting tools may be greater or less than that shown in the drawings. It is also clear that by suitable axial arrangement of a plurality of cutting tools on a single cutter, and by the establishment of a suitable timed relation between the cutter and the gear to be chamfered, a plurality of tools may serve to successively engage and chamfer successive teeth on the gear. Various other alterations of this arrangement will occur to one skilled in the art.

Where a number of cutting tools are employed on a single cutter, it is of course necessary to provide for axial movement of the cutter on its supporting shaft during the period of engagement of each cutting tool with the gear. One form of cam suitable for this purpose is illustrated in the development of Figure 13 of the drawings, the cam 144 on the stationary cam element 145 being successively contacted by cams 146 on the cutter 148, each of the cams 146 corresponding to one of the cutting tools 149 and being effective during engagement of that cutting tool with a tooth of the gear. The cams 146 are of the type which would be employed in a construction such as that shown in Figure 1 in the event the gear 38 were provided with a right-hand helix, cutting being effected on the leading rather than the trailing edge of each tooth. Obviously, however, cutting may be effected on either the leading or the trailing edge of the tooth regardless of the direction of the helix, it being a relatively simple matter to rotate the gear to be chamfered in a direction opposite to that in which it is rotated in Figure 1, it being only necessary to so design the cooperating cam surfaces as to effect the required reciprocation of the cutter during the chamfering operation. The arrangement of the cutting tools shown in Figure 13 corresponds to that shown in Figure 10, the tools being adapted to effect successive cuts of increasing depth on one and the same tooth.

It will be observed that the invention contemplates the chamfering by means of a single cutting operation of the entire edge of the tooth from the outer end to the root, operation of the machine being by no means dependent upon movement of the gear to be chamfered into a series of positions with respect to the cutter. In other words, the operation is preferably based on the execution of a complete cut rather than a series of partial cuts on different portions of the edge of the tooth such as would ordinarily be effected if a hobbing tool were employed. As a result, the machine may be operated at a maximum speed and with unusual efficiency and accuracy.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. In a machine for chamfering gear teeth, the combination with a support for a gear to be chamfered, a cutter supported for movement in a plane intersecting the plane of the gear into cutting engagement with the end of a gear tooth, and means for imparting relative movement to said cutter and gear in a direction generally parallel to the plane of the gear during contact of the cutter and tooth to an extent sufficient to compensate for the tooth slope.

2. In a machine for chamfering gear teeth, the combination with a support for a gear to be chamfered, a cutter supported for movement in a plane intersecting the plane of the gear into cutting engagement with the end of a gear tooth, means for imparting relative movement to said cutter and gear in a direction generally parallel to the plane of the gear during contact of the cutter and tooth to compensate for the tooth slope, and means for rotating said gear continuously on the axis thereof in timed relation with the movement imparted to said cutter, whereby

successive teeth may be presented to said cutter.

3. In a machine for chamfering gear teeth, the combination with means for supporting a gear for rotation on the axis thereof, of a cutter supported for rotation on an axis transverse to the axis of said gear, said cutter having a cutting edge, and means for continuously rotating said gear and cutter in timed relation to bring the cutting edge of said cutter into successive cutting engagement with the edge of the teeth of the gear over the entire depth of each tooth on each cut, said cutter being so formed as to effect a single cut only on each of the engaged teeth during one complete rotation of said gear.

4. In a machine for chamfering gear teeth, the combination with means for supporting a gear for rotation on the axis thereof, of a cutter supported for rotation on an axis transverse to the axis of said gear, means for continuously rotating said gear and cutter in timed relation to bring said cutter into successive cutting engagement with the edge of the teeth of the gear, and means for reciprocating said cutter on the axis thereof during engagement of said cutter and gear teeth.

5. In a machine for simultaneously chamfering the several gear units of a gear cluster, the combination with means supporting the gear cluster for rotation on the axis thereof, a plurality of cutters, one associated with each gear unit, means supporting each cutter for rotation on an axis transverse to the axis of the associated gear unit, means for rotating said gear cluster and said cutters in timed relation and at such relative speeds as to complete the chamfering of the several gear units simultaneously, and means for reciprocating each cutter on the axis thereof during cutting engagement with the associated gear unit to compensate for the tooth slope and the rotational movement of the gear cluster.

6. In a machine for simultaneously chamfering opposite ends of the teeth of a gear, the combination with means supporting the gear for rotation, separate cutters supported for rotation about axes transverse to the axis of rotation of said gear and adjacent opposite faces of the gear, means for rotating said gear and cutters in timed relation, and means for imparting axial reciprocatory movement to said cutters during engagement of the latter with said gear teeth.

7. In a machine for chamfering gear teeth, the combination with a support for a gear to be chamfered, of a cutter supported for movement in a plane intersecting the plane of the gear into cutting engagement with the end of a gear tooth, means for imparting relative movement to said cutter and gear in a direction generally parallel to the plane of the gear during contact of the cutter and tooth to compensate for the tooth slope, and means for effecting relative rotative adjustment of said cutter and gear about an axis generally parallel to the plane of said gear to vary the chamfer angle.

8. In a machine for chamfering gear teeth, the combination with means for supporting a gear for rotation on the axis thereof, of a cutter supported for rotation on an axis transverse to the axis of said gear, and means for continuously rotating said gear and cutter in timed relation to bring said cutter into successive cutting engagement with the edge of the teeth of the gear, said last named means including pivoted gearing operatively connecting said gear and cutter, the members of said gearing being relatively displaceable about an axis generally parallel to the plane of said gear, whereby the angle of chamfer may be varied without affecting the operative connection between gear and cutter.

9. In apparatus for chamfering gear teeth, the combination with a rotatable shaft, a cutting tool mounted on said shaft, means supporting a gear to be chamfered for rotation on an axis transverse to the axis of said shaft and adjacent the path of movement of said tool, gearing connecting said gear and shaft for rotation in timed relation, and means for effecting axial displacement of said tool during engagement of said tool and gear.

10. In apparatus for chamfering gear teeth, the combination with a rotatable shaft, a cutting tool mounted on said shaft, means supporting a gear to be chamfered for rotation on an axis transverse to the axis of said shaft and adjacent the path of movement of said tool, gearing connecting said gear and shaft for rotation in timed relation, and means for effecting axial displacement of said tool during engagement of said tool and gear, said last named means including a support for said tool rotatable with and reciprocable on said shaft, and a stationary cam cooperating with said support.

11. In apparatus for chamfering gear teeth, the combination with a rotatable shaft, a cutting tool mounted on said shaft, means supporting a gear to be chamfered for rotation on an axis transverse to the axis of said shaft and adjacent the path of movement of said tool, gearing connecting said gear and shaft for rotation in timed relation, means for effecting axial displacement of said tool during engagement of said tool and gear, said gearing including a worm on said shaft, and a countershaft having gears meshing with said worm and said gear to be chamfered.

12. In a machine for chamfering gear teeth, the combination with a support for a gear to be chamfered, a cutter supported for movement in a plane intersecting the plane of the gear into cutting engagement with the end of a gear tooth, and means for imparting relative movement to said cutter and gear in a direction generally parallel to the plane of the gear during contact of the cutter and tooth to an extent sufficient to compensate for the tooth slope, said cutter comprising a plurality of separate cutting tools so positioned as to effect successive chamfering cuts on the same tooth.

13. In a machine for chamfering gear teeth, the combination with means for supporting a gear for rotation on the axis thereof, of a cutter supported for rotation on an axis transverse to the axis of said gear, and means for continuously rotating said gear and cutter in timed relation to bring said cutter into successive cutting engagement with the edge of the teeth of the gear, said cutter comprising a plurality of separate cutting tools circumferentially and axially spaced for respective engagement with successive gear teeth.

14. The method of chamfering spur gear teeth which comprises rotating a cutter about an axis transverse to the axis of the gear to cause the cutting edge of the cutter to engage a tooth adjacent the intersection of an end face and a working face and to move over substantially the entire depth of the tooth, and effecting during such movement a relative bodily displacement of the cutter and gear resulting in a relative circumferential displacement of the gear and the point of contact of the cutting edge with the tooth corresponding generally to the tooth slope to produce a cut of substantially uniform depth.

15. The method of chamfering spur gear teeth which comprises rotating a cutter about an axis transverse to the axis of the gear to cause the cutting edge of the cutter to engage a tooth adjacent the intersection of an end face and a working face and to move over substantially the entire depth of the tooth from the outer end of the tooth toward the base of the tooth, and effecting during such movement a relative bodily displacement of the cutter and gear resulting in a relative circumferential displacement of the gear and the point of contact of the cutting edge with the tooth corresponding generally to the tooth slope to produce a cut of substantially uniform depth.

16. In a machine for chamfering gear teeth, the combination with means for supporting a gear for rotation on the axis thereof, of a cutter supported for rotation on an axis transverse to the axis of said gear, means for continuously rotating said gear and cutter in timed relation to bring said cutter into successive cutting engagement with the edge of the teeth of the gear over the entire depth of each tooth, and means for effecting during cutting a relative circumferential displacement of the gear and the point of cutting action corresponding generally to the tooth slope.

17. In a machine for chamfering gear teeth, the combination with a support for a gear to be chamfered, of a cutter supported for movement in a plane intersecting the plane of the gear into cutting engagement with the end of a gear tooth, and means for effecting relative rotative adjustment of said cutter and gear about an axis generally parallel to the plane of said gear to vary the chamfer angle.

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