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METHOD OF AND MACHINE FOR GRINDING GEARS

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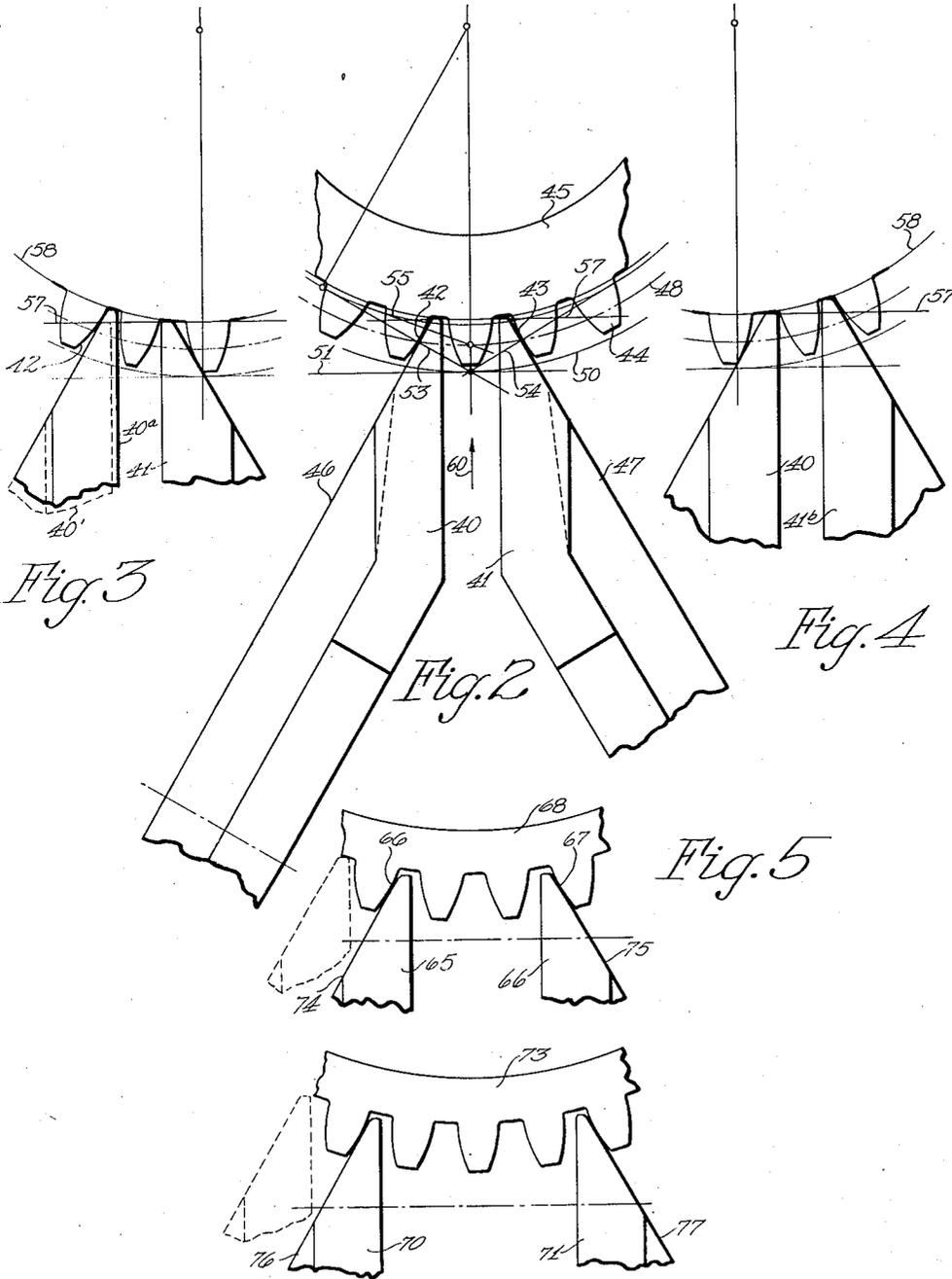


Fig. 6

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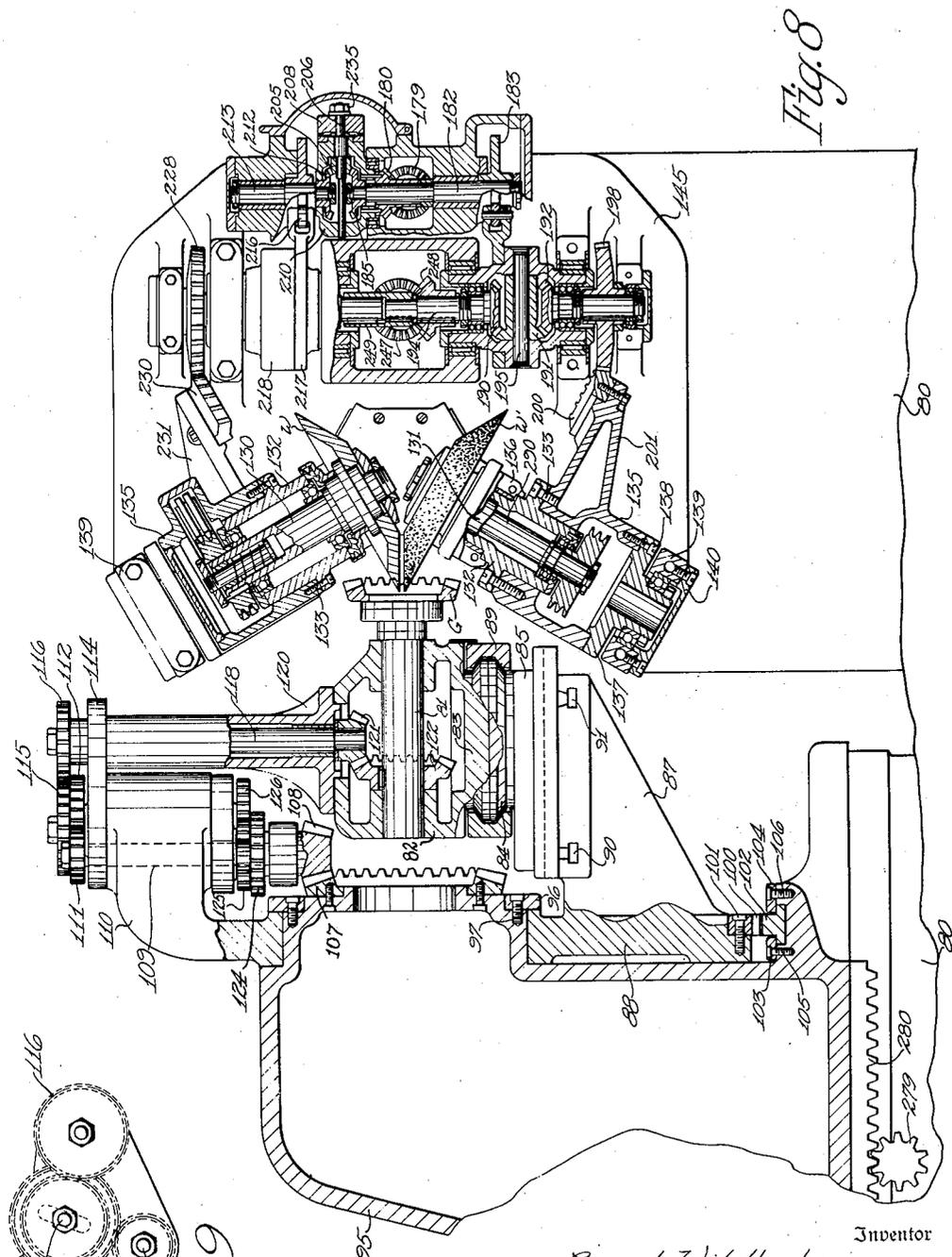


Fig. 8

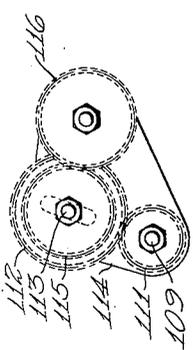


Fig. 9

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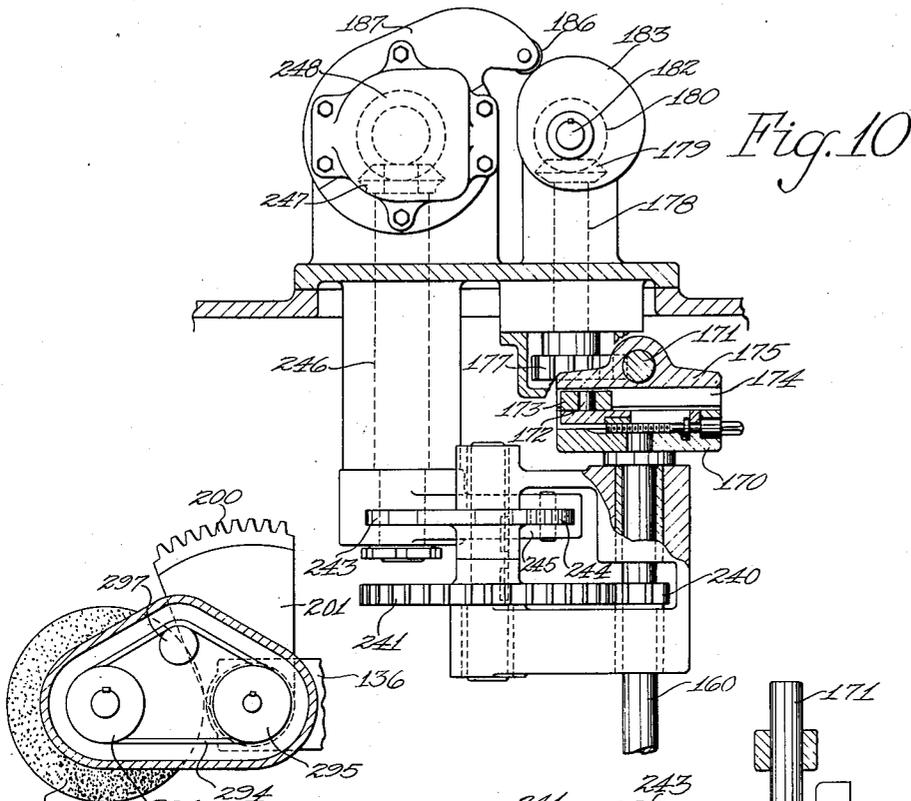


Fig. 10

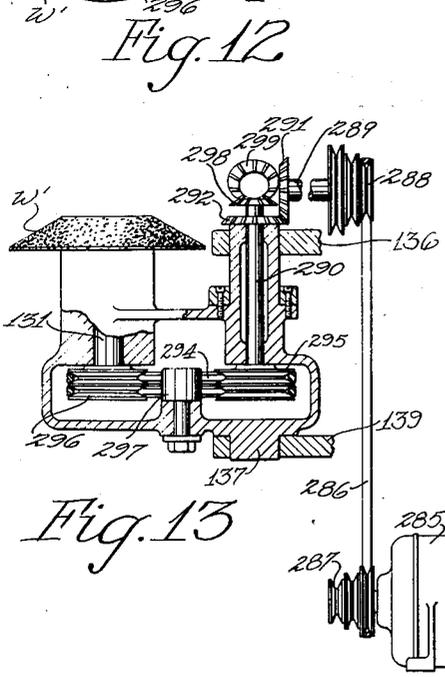


Fig. 12

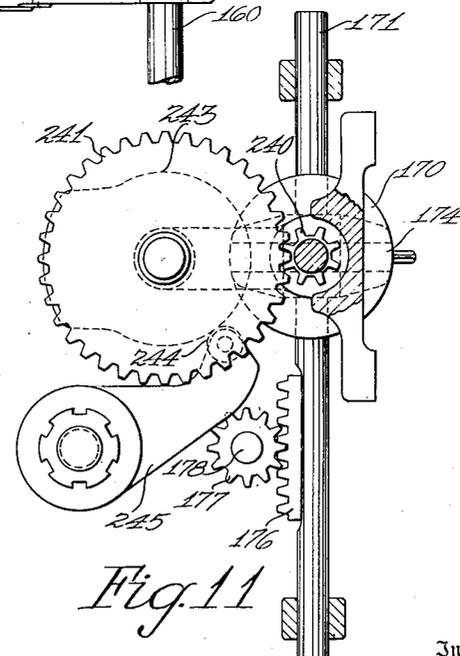


Fig. 11

Fig. 13

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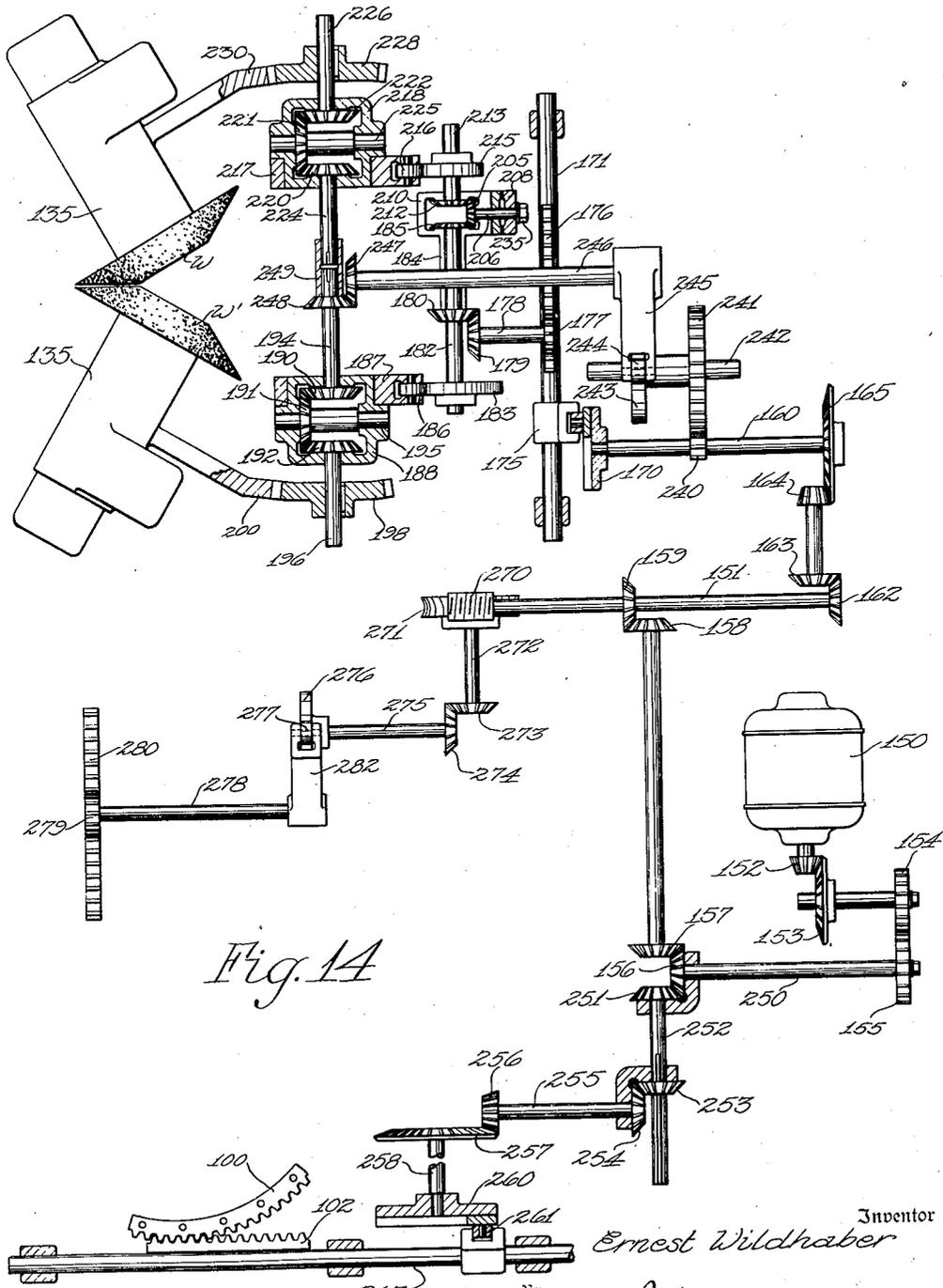


Fig. 14

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# UNITED STATES PATENT OFFICE

2,164,978

## METHOD OF AND MACHINE FOR GRINDING GEARS

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12 Claims. (Cl. 51—123)

The present invention relates to the grinding of straight toothed gears both spur and bevel, and particularly to the grinding of such gears in a generating operation with a plane-sided wheel.

Heretofore two principal methods of grinding straight toothed gears in a generating process have been used. In one of these methods, a plane-sided grinding wheel of relatively large diameter is employed and the wheel is fixed against movement longitudinally of the teeth of the gear and the tooth surfaces of the gear are ground by simply rotating the wheel on its axis while effecting the relative generating roll between the wheel and the gear. In the other method, the grinding wheel, which may be either a plane-sided or a conical wheel, is moved relatively longitudinally along a tooth of the gear as the wheel is rotated on its axis and the wheel and gear are rolled relative to one another. The first method is quite fast but is restricted to use in the grinding of gears of narrow face-width. The second method is relatively slow because to grind the full tooth surfaces of a tooth, the grinding wheel must be rolled with the gear not merely in one position, as in the first method, but continuously back and forth as the wheel moves relatively lengthwise of the tooth surface being ground.

One main object of the present invention is to provide a method of grinding straight toothed gears which is capable of handling gears of greater face-width than heretofore possible but which will not require any feed motion along the length of a tooth of the gear.

Another object of the invention is to provide a method of generating straight toothed gears which will permit of employment of a stronger type of grinding wheel than has heretofore been possible in the generating methods heretofore practiced.

A further object of the invention is to provide a method of grinding straight toothed gears in which a pair of grinding wheels may be employed for grinding opposite sides of the teeth of a gear simultaneously and the wheels used will have a longer life and a larger usable amount of abrasive stock than wheels usable with the processes heretofore employed.

Still another object of the invention is to provide a method of grinding straight toothed gears in which a pair of grinding wheels may be employed and the wheels may be set to a constant angle and adjusted jointly to compensate for wear and to permit dressing.

A still further object of the invention is to provide a method for grinding straight toothed gears which will require a minimum amount of generating roll and, in fact, no more roll for two wheels than would be required if a single wheel only were used in the grinding process.

Other objects of the invention will appear hereinafter from the specification and from the recital of the appended claims.

In the drawings:

Fig. 1 is a diagrammatic view showing the relative positions of a grinding wheel and gear at different points in the roll in the process of grinding a gear by the method of the present invention and showing, also, by way of comparison, the corresponding positions of wheel and gear in the grinding methods heretofore employed;

Fig. 2 is a diagrammatic view showing how a pair of grinding wheels, whose pressure angles are greater than the pressure angles of the tooth surfaces to be ground, may be employed in grinding gears according to one modification of the present invention;

Figs. 3 and 4 are diagrammatic views illustrating, respectively, positions of the grinding wheels shown in Fig. 2, at opposite ends of the roll in the generation of a gear;

Figs. 5 and 6 are diagrammatic views showing how the amount of generating roll may be kept at a minimum on gears of different numbers of teeth without altering the relative angular positions of the two grinding wheels, by spacing the wheels different numbers of teeth apart;

Fig. 7 is a diagrammatic view, further illustrating the different positions which a grinding wheel assumes in the grinding of gears according to the present invention;

Fig. 8 is a longitudinal view, with parts broken away and shown in section, of a grinding machine built according to one embodiment of this invention for grinding straight toothed bevel gears;

Fig. 9 is a view, showing a detail of the drive to the work spindle;

Figs. 10 and 11 are views showing details of the drive of the wheel carriers, the view of Fig. 11 being taken at right angles to the view of Fig. 10 and from below;

Figs. 12 and 13 are views taken at right angles to one another and showing a detail of the drive to one of the grinding wheels of the machine;

and Fig. 14 is a drive diagram of the machine.

The present invention deals directly with the grinding of gears with a plane-sided wheel where the wheel has no movement longitudinally of the

gear teeth. Heretofore, in grinding the involute or substantially involute tooth sides of a straight toothed gear with such a wheel, the grinding wheel and the gear have simply been rolled together as though the gear were meshing with a rack or crown gear represented by the wheel. In the present method, the generating roll is retained, but in addition, the grinding wheel is fed depthwise into the gear being ground, as it rolls with the gear, so that at one or both ends of the roll it may engage with the teeth of the gear at a greater depth than would be possible in a pure rolling motion and hence may grind the sides of the gear teeth to a greater depth than has heretofore been possible.

The old and new methods of grinding are illustrated for comparison in Fig. 1.

In this figure, 20 denotes the gear to be ground and 21 the grinding wheel. The active grinding surface of the wheel is denoted at 22 and lies in a plane perpendicular to the axis 23 of the wheel.

Root, pitch and top surfaces of the gear are denoted at 25, 26 and 27, respectively and the root and pitch planes of the gear are denoted at 28 and 29, respectively. The pitch plane is the common plane tangent to the pitch surfaces of the gear being ground and of the basic gear represented by the grinding wheel. In spur and bevel gears, the pitch plane is perpendicular to the plane containing the axes of the gear being ground and of the basic generating gear represented by the grinding wheel.

In Fig. 1, the grinding wheel is shown as positioned to grind the side surfaces 30 of the gear teeth 31 and the wheel is adjusted angularly so that its active side surface 22 is inclined to the pitch plane 29 of the gear at an angle equal to the pressure angle of the tooth surfaces 30 to be ground.

In the prior-art method of grinding, the pitch surface 26 of the gear is rolled on the pitch plane of the rack or crown gear represented by the wheel. This plane coincides with the plane 29.

If we imagine that in such prior process, the generating roll is divided, that is that the gear turns on its axis which remains stationary and that the wheel 21 moves in the direction of the pitch plane 29, then the outside or tip point of the wheel will move on the line 28 and at opposite ends of the roll, the wheel will assume the positions denoted at 21' and 21''.

In the position shown in dotted lines at 21', the wheel will grind and completely form the root portion or flank of the tooth sides 30 in the middle section of the gear. At the ends of the tooth, however, the wheel does not reach quite so deep into the tooth space because it is circular (see Fig. 7) and at a certain distance away from the center of the tooth face, stock will be left on the tooth surfaces which will interfere with the mesh between the gear and its mate. The distance at which interfering stock may be left on the tooth sides determines the maximum face-width, of the gears which may be ground by the previous process without motion of the wheel longitudinally of the tooth surfaces of the gear. The limit face width equals twice said distance.

In the process of the present invention, an additional motion is provided between the work and the grinding wheel in the plane of the active surface of the grinding wheel during the rolling motion. The grinding wheel is fed deeper into the tooth space of the gear at one or both ends of the roll. Thus, as shown in Fig. 1, in the method of the present invention, the grinding

wheel is moved deeper into the tooth space 32 of the gear as the wheel rolls from the central position 21 to the left and will have the position 21a instead of the position 21'. The grinding wheel will then reach beyond the root plane 28 of the gear at this end of the roll and finish the lower flank of the tooth side 30 more completely than was possible in the previous process. Hence gears of increased face-width may be ground by the process of the present invention without longitudinal movement of the grinding wheel. The grinding wheel may be advanced in the direction of its active surface until it nearly touches the root surface 25 of the gear being ground.

The described feed motion in the plane of the grinding wheel is timed with the generating roll. It does not need to be very accurately timed to the roll, however, nor does the motion itself require particular accuracy inasmuch as it does not affect the shape of the tooth surfaces but only the extent of the finished portion of these surfaces.

The same mechanism which is employed to produce the described motion in the plane of the active surface of the grinding wheel may also be used to effect withdrawal of the wheel from engagement with the gear after a tooth surface has been ground to permit of indexing the gear. This is shown clearly in Fig. 7, where two positions of the wheel, at full depth and in withdrawn position, are shown in full and dotted lines, respectively. Here the feed of the wheel into depth is assumed to take place about an axis 35 and the center of the wheel in the two positions of its movement is denoted at 36 and 36', respectively.

In the rolling movement of the wheel 21 to the right (Fig. 1) in the grinding of the tooth surfaces 30 of the gear 20, it is not necessary to employ a feed motion in the direction of the plane surface of the wheel since in this direction of roll, the grinding wheel is operating upon the portion of the tooth surface 30 adjacent the tip of the tooth. It is desirable, however, to employ this motion during roll of the wheel to the right, also, for by imparting this feed motion to the wheel in this direction of the roll, also, wear of the grinding wheel is distributed over an increased length of the wheel profile. Hence it is desirable to move the wheel inwardly from the position 21 to a position such as indicated in dotted lines at 21b as the wheel moves to the right. Thus at the right end of the roll, the wheel also, will extend deeper into the tooth space of the gear than at the position 21'.

The advantage of using the feed motion in the plane of the active surface of the grinding wheel is increased where the gear is ground conjugate to a rack or crown gear whose tooth surfaces have a pressure angle greater than the pressure angle of the gear to be ground. This is illustrated in Figs. 2, 3 and 4.

Here are shown two grinding wheels 40 and 41 for grinding opposite side surfaces 42 and 43, respectively, of the teeth 44 of the gear 45.

The wheels have active surfaces 46 and 47, respectively, which are plane surfaces perpendicular to the axes of the wheels and they are adjusted angularly so that their plane side surfaces are inclined to the pitch surface 48 of the gear at an angle greater than the pressure angle of the tooth surfaces to be ground.

To attain the proper tooth profiles and pressure angles on the gear 45, then, the gear is rolled not on its pitch circle 48, but on a circle 50 which is larger than its pitch circle and which rolls on

the line 51, that represents the pitch plane of the basic rack or crown gear, represented by the wheels during the generating operation. 53 and 54 are lines of action between the gear and the grinding wheels during generation of the tooth profiles, whereas 55 is a line of action between the gear and its mate when the pair are in mesh.

Figs. 3 and 4 show, respectively, positions of the gear and wheels at opposite ends of the generating roll.

With prior methods of grinding, the tip surfaces of the grinding wheels remain outside, that is, above the tangent 57 to the root surface 58 of the gear so that the wheels occupy the positions indicated at 40' and 41, respectively, at the left end of the roll in Fig. 3. With this arrangement, however, stock will be left on the lower flank of the sides 42 of the teeth of the gear and this stock will prevent correct mesh when the gear is run with its mate. Hence the face-width of the gear which may be ground is definitely limited.

With the method of the present invention, however, the grinding wheel 40 is fed in depth-wise as it rolls with the gear and will occupy the position indicated at 40a at the left end of the roll through displacement of the wheel in its plane 46 and the tooth surface will be finished to a greater depth and hence to a greater width. Correspondingly in the rightward roll of the wheel, the wheel 41 will be moved inwardly below the tangent 57 and will occupy the position denoted at 41b in Fig. 4 so that the opposite sides 43 of the gear teeth may be properly finished.

It is even possible with the present invention to undergrind the tooth flanks with the flat sides of the grinding wheel, if so desired, by further extending the roll.

One advantage obtained by the use of an increased pressure angle for generation is the fact that the grinding wheels or wheel may be adjusted for dressing in a direction 60 perpendicular to the direction of roll whereas, otherwise, as indicated in Fig. 1, the grinding wheel must be adjusted in an oblique direction, as denoted at 61, unless a much weaker form of grinding wheel is used.

Another advantage of the use of an increased pressure angle for generation is that the wheels can be kept more readily clear of one another and hence stronger and longer-lived wheels can be employed. Preferably the grinding wheels are set to a constant angle and are jointly adjusted for dressing.

On gears with moderate numbers of teeth, such as shown in Figs. 1 and 2, the provision of the increased pressure angle helps to reduce the total roll required to fully generate both sides of the gear teeth. In the generation of a gear such as shown in Fig. 2 with a pair of plane sided wheels, the total roll required is not any larger for the two wheels than it would be for a single wheel.

Figs. 5 and 6 show how the amount of roll may be kept small even with gears having larger numbers of teeth, without altering the relative angular position of the two wheels. In Fig. 5, the two grinding wheels 65 and 66 are spaced two tooth spaces apart in the grinding of the opposite sides 66 and 67 of the teeth of the gear 68. In Fig. 6, the grinding wheels 70 and 71 are spaced three tooth spaces apart in the grinding of the opposite sides of the teeth of the gear 73 which has a greater number of teeth than either the gear 68 or the gear 45. In all of the cases 75 illustrated in Figs. 2, 5 and 6, however, the angle

between the plane sides of the grinding wheels remains constant, that is, the angle between the sides 46 and 47 in Fig. 2 is equal to the angle between the sides 74 and 75 in Fig. 5 and the sides 76 and 77 in Fig. 6. Further, with the arrangements shown in Figs. 5 and 6, it is possible to keep the roll as small as it would be where a single wheel is used.

In Figs. 8 to 14 inclusive, I have illustrated more or less diagrammatically one form of machine for grinding straight bevel gears according to this invention.

80 designates the base or frame of the machine, G is the bevel gear blank to be ground and W and W' are the grinding wheels.

The gear to be ground is secured in any suitable manner to a work spindle 81 which is journaled in a work head 82. The work head 82 is formed with a circular-shaped foot portion 83 which seats on the upper face of a circularly-shaped rest 84 which forms a part of a sliding base 85.

The base 85 is laterally adjustable upon a supporting bracket 87 which is integral with the face-plate or cradle 88.

The foot 83 of the work head and the supporting rest 84 of the base 85 have oppositely beveled peripheral surfaces. The work head is angularly adjustable on the rest 84 to position the work spindle in accordance with the cone angle of the gear to be ground and the work head may be secured to the supporting base in any position of its angular adjustment by the clamping ring 89. This ring is of the split type and is formed internally with a generally V-shaped groove, the opposite sides of which engage with the beveled surfaces of the foot portion 83 and of the supporting rest 84. The work head is shown swung out of operative position in Fig. 8.

Adjustment of the slide 85 upon the bracket 87 permits of adjustment of the work spindle in accordance with the cone distance of the gear to be ground. The slide 85 may be secured to the bracket 87 in any adjusted position by T-bolts (not shown) which engage in the slots 90 and 91.

The cradle 88 is journaled on a column or upright 95 and is secured in position on the column by the circular gib 96 and the screws 97. The column 95 is slidably mounted upon the base 80 of the machine and is reciprocable thereon to move the gear into and out of engagement with the grinding wheel, as will be described in more detail hereinafter.

There is a spur gear segment 100 secured to the cradle 88 by screws 101. This segment meshes with a rack 102 which is reciprocably mounted upon the column 95 and which is held in position on the column by the straps 103 and 104 and the screws 105 and 106. The rack 102 is reciprocated by means which will be described more particularly hereinafter to impart an oscillating motion to the cradle.

Fixedly secured to the column 95 in a position coaxial of the cradle is a bevel gear 107. A bevel pinion 108 meshes with this bevel gear. This pinion is secured to a shaft 109 which is journaled in a bracket-like extension 110 of the cradle 88.

There is a spur gear 111 secured to the outer end of this shaft and this spur gear meshes with a spur gear 112 which is mounted upon a stud 113 that is secured in a quadrant 114. The quadrant 114 is mounted upon the bracket 110 so as to be adjustable angularly about the axis of the shaft 109. There is a second spur gear 115 75

mounted upon the stud 113 and this gear meshes with a spur gear 116 which is secured to the shaft 118.

This shaft is journaled in a sleeve 120 which is secured in any suitable manner to the work head 82. There is a bevel pinion 121 keyed to the lower end of this shaft and this pinion meshes with a bevel gear 122 which is keyed to the work spindle 81.

Through the gearing described, it will be seen that when the rack 102 is reciprocated, an oscillatory movement will be imparted to the cradle 88 and simultaneously the work spindle 81 will be rotated in one direction or the other upon its axis. Thus the generating motion is imparted to the work.

The machine is of the intermittent indexing type. The indexing mechanism employed may be of any suitable type and may be located at any suitable position upon the machine. It may be mounted, for instance, upon the bracket 110 and may be driven from the shaft 109 through spur gear 124, a spur gear (not shown) which meshes with said gear, and the spur gears 125 and 126.

The grinding wheels W and W' are secured to wheel spindles 130 and 131, respectively. Each of these spindles is journaled in a holder 132 which is secured by screws 133 to a wheel carrier 135.

Each of the wheel-carriers 135 is journaled in a bearing 136 (Fig. 12) and each wheel carrier 135 has a trunnion 137 secured to it by screws 138 that is journaled in a bearing 139 which is of the split type and is closed by an end-cap 140.

The bearings 136 and 139 are integral with an upright or column 145 which is integral with or secured to the base 80 of the machine. Thus, the grinding wheel carriers are rotatably mounted upon the column 145 for oscillation to effect the depthwise movement of the wheels as will now be described. Mounted at any convenient point upon the machine is a main drive motor 150 (Fig. 14). This motor drives a shaft 151 through the bevel gearing 152, 153, the spur gears 154 and 155, the bevel gears 156 and 157 and the bevel gears 158 and 159. The shaft 151 drives a shaft 160 through the bevel gears 162 and 163, and the bevel gears 164 and 165.

Secured to one end of the shaft 160 (Fig. 14, 10 and 11) is a crank 170 which drives a rod 171 through an adjustable pin 172 and the block 173. The block engages in a longitudinal slot 174 formed in a member 175 which is fastened in any suitable manner to the rod 171.

There is a rack member 176 secured to the rod 171 and this rack member meshes with a spur pinion 177 which is fastened to a shaft 178. Secured to the upper end of this shaft is a bevel gear 179 which meshes and drives a bevel gear 180. The gear 180 formed with an integral sleeve or projection 184 which is keyed to a shaft 182 and is secured to a differential housing 210. Keyed to one end of the shaft 182 is a cam 183 and fastened to the other end of the shaft is a bevel gear 185.

The cam 183 engages with a roller 186 which is carried by an arm 187 that is secured to a differential housing 188. Mounted in the differential housing are bevel gears 190, 191 and 192. The bevel gear 190 is secured to a shaft 194. The bevel gear 191 is a planetary gear and is mounted upon a shaft 195 which is journaled at both ends in the housing 188. The bevel gear 192 is secured to a shaft 196 which projects from one end of the housing and which is keyed to a bevel

gear 198 (Figs. 14 and 8). This bevel gear 198 meshes with a bevel gear segment 200 which is bolted to an arm 201 that is integral with the wheel carrier 135 for the wheel W'.

The bevel gear 185 meshes with a bevel pinion 205 that is secured to a stud shaft 206. This stud shaft is journaled in the differential housing 210 and is keyed to a face-clutch member 208 which has clutch teeth on its inside face that are adapted to be engaged with clutch teeth formed on the opposed face of the differential housing.

The pinion 205 meshes with a bevel gear 212 which is secured to a shaft 213.

Keyed to the shaft 213 is a cam 215 that engages a roller 216 carried by an arm 217. The arm 217 is secured to a differential housing 218. Mounted in this housing are the bevel gears 220, 221 and 222. The bevel gear 220 is secured to a shaft 224, one end of which is journaled in the differential housing. The bevel gear 221 is a planetary gear and is secured to a shaft 225, which is journaled at both ends in the housing 218. The bevel gear 222 is secured to a shaft 226, which is journaled at one end in the housing. There is a bevel gear 228 keyed to the shaft 226. This bevel gear meshes with a bevel gear segment 230 which is bolted to an arm 231 that is integral with the carrier 135 for the wheel W.

Through the mechanism above described, it will be seen that the cams 183 and 215 are rotated first in one direction and then in the other. As these cams oscillate, they impart an oscillatory movement to the segments 200 and 230, respectively, through the differential housings 188 and 218, respectively, and the gearing connecting these housings with the segments. Thus the carriers 135 are oscillated imparting oscillating movement to the wheels W and W' in the planes of the active side surfaces of these wheels. Thus, the desired depthwise movement may be imparted to the wheels to effect grinding of the tooth surfaces of a gear to a greater depth according to the described basic principle of this invention.

The cams 183 and 215 are similar in conformation and are of opposite hand since one grinding wheel is fed depthwise in the movement toward one end of the roll and the other wheel is fed depthwise in the movement toward the opposite end of the roll, as will clearly be seen from Figs. 3 and 4. The cams 183 and 215 impart the same movement when turned in opposite directions. The cams 183 and 215 can be adjusted angularly relative to one another by disengaging the clutch member 208 and rotating the shaft 206 while the clutch is open. The clutch member is held in engaged position by the nut 235 which threads onto the outer end of the shaft 206.

To effect indexing of the work after grinding of a pair of tooth surfaces, the grinding wheel carriers are swung about their respective axes to withdraw the wheels from the gear and then the index mechanism is actuated. After indexing is complete, the carriers are swung back to return the wheels to operative position. The mechanism for effecting the withdrawal and return movements of the wheels will now be described.

Secured to the shaft 160 is a spur pinion 240 (Figs. 14, 10 and 11). This pinion meshes with a spur gear 241 which is keyed to a shaft 242. Keyed to the shaft 242 is a cam 243. This cam engages a roller 244 which is carried by an arm 245.

The arm 245 is secured to a shaft 246. Fastened to this shaft is a bevel gear 247. This bevel gear meshes with a bevel gear 248 which is keyed to the shaft 194. The shaft 194 is aligned axially with the shaft 224 and the two shafts are connected together to rotate together by a coupling 249 (Figs. 8 and 14). Through the mechanism just described and the differentials 188 and 218, the withdrawal and return movements of the wheels are effected.

The generating motion is derived from the shaft 250 through the bevel gears 156 and 251, the shaft 252, the bevel gears 253 and 254, the shaft 255, the bevel gears 256 and 257, the shaft 258, the crank 260, crank-pin 261, rod 263, rack 102 and spur gear segment 100.

The gear being ground is thus rolled back and forth under the oscillating grinding wheels.

In the machine illustrated, it is intended to roll the work back and forth several times over the grinding wheels before withdrawing the wheels and indexing. For this reason, the gearing 240-241 is selected so that the crank 170 will rotate several times for a single revolution of the cam 243.

To effect gradual removal of stock and also to avoid repeated grindings in the same positions on the gear on successive roll movements, the gear is fed slowly into the wheels during the rolling movements.

The feed movement is imparted to the column 95. This movement is derived from the shaft 151, the drive being through the worm 270 and worm wheel 271, shaft 272, bevel gears 273 and 274, shaft 275, cam 276, roller 277 which engages said cam, shaft 278, spur pinion 279 (Figs. 8 and 14), and rack 280. The roller 277 is carried by an arm 282 which is keyed or otherwise secured to the shaft 278.

The grinding wheels may be driven in any suitable manner. As shown in the drawings, both wheels are driven from the same motor 285 (Fig. 13) which is mounted in any convenient location upon the machine. This motor is connected by a belt 286 (Fig. 13) and a pair of pulleys 287 and 288 with a shaft 289. This shaft drives the shaft 290 through a pair of mitre gears 291 and 292. The shaft 290 drives the spindle 131 of the grinding wheel W' through the belting 294 and pulleys 295 and 296. An idler 297 is provided to take up slack in the belting. The other grinding wheel W is driven from the shaft 290 through the mitre gears 298 and 299. The mitre gear 299 is secured to a shaft 290 which extends parallel to the wheel spindle 130 and like the shaft 290 carries a pulley which drives the wheel spindle 130 through a drive corresponding to the pulley drive described for the wheel spindle 131. The mountings of the shaft 290 and wheel carrier are shown more or less diagrammatically in Fig. 13 for the sake of clearness in illustration.

The operation of the illustrated machine will be apparent from the above description but may briefly be summed up here. After the various adjustments are made, the machine may be started. When the gear is in operative position, the generating roll starts and the grinding wheels rotate on their axes while the gear is rolled over them. During each rolling movement, the wheel carriers are oscillated to effect the depthwise movement. During relative movement of gear and wheels toward one end of the roll, the wheel W is moved into extra depth and during relative movement toward the other end of the roll, the

wheel W' is moved into extra depth. The gear is rolled back and forth over the wheels several times before it is indexed and during these rolling movements, the gear is gradually fed into depth. When the tooth surfaces have been fully ground, the wheels are swung away from the gear by movement of the wheel carriers and when the wheels have been fully withdrawn, the gear is indexed. At this time also, the column 95 is withdrawn the amount of the previous feed movement. When the indexing operation is completed, the cycle begins anew, the wheels being returned into engagement with the gear and the roll and feed movements beginning again. The alternate grinding and indexing proceeds until all of the teeth of the gear have been finish-ground. Then the machine may be stopped by automatic means such as usually employed on machines for producing gears and the completed gear may be removed and a new gear chucked.

No dressing mechanism has been shown upon the machine, but the dressing mechanism may be of any suitable type. If the wheels are adjusted and the roll gearing is so selected that the wheels represent a basic gear having teeth of larger pressure angle than the tooth surfaces of the gear to be ground, the dressing mechanism may be advanced relatively toward the wheels along a line bisecting the angle between the plane side surfaces of the wheels. Likewise, wear of the wheels can be compensated for by movement of the column 95 to feed the gear into the wheels. The angle between the wheel spindles may be kept constant and gears of different tooth numbers may be ground with the wheels spaced different distances apart, as shown in Figs. 5 and 6. A suitable adjustment to permit of spacing the wheels for this purpose may be provided, but has not been shown upon the machine illustrated in the drawings.

In the drawings, the invention has been illustrated in connection with a machine for grinding straight bevel gears conjugate to a crown gear having plane tooth sides. It will be understood, however, that the invention is also applicable to the grinding of straight bevel gears conjugate to a non-generated or "Formate" gear. It will also be understood, as already mentioned, that the invention is applicable to the grinding of spur gears and that the spur gears may be ground conjugate to a rack or to a non-generated spur gear. This application is intended to cover any adaptations, uses, or embodiments of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the gear art and as may be applied to the essential features hereinbefore set forth and as fall within the scope of the invention or the limits of the appended claims.

Having thus described my invention, what I claim is:

1. The method of grinding a gear which consists in employing a grinding wheel which has a plane active face extending at right angles to the axis of the wheel, positioning said wheel in engagement with the gear so that the axis of the wheel is inclined to the pitch plane of the gear, and rotating the wheel on its axis and producing a relative rolling movement between the gear and the wheel to cause the plane active face of the wheel to grind a side surface of a tooth of the gear, while effecting a relative depthwise feed movement between the wheel and gear in time with the relative rolling movement so that the

wheel will grind to a greater depth at one end of the rolling movement.

2. The method of grinding a gear which consists in employing a grinding wheel which has a plane active face extending at right angles to its axis, engaging said wheel with the gear so that the axis of the wheel is inclined to the pitch plane of the gear at an angle equal to the pressure angle of the tooth surfaces to be ground, rotating the wheel on its axis and producing a relative rolling movement between the wheel and gear while effecting a relative depthwise feed movement between the wheel and gear in the direction of the plane side surface of the wheel in time with the rolling movement so that at one end of the rolling movement, in full depth position, the wheel will extend inside the root plane of the gear.

3. The method of producing a gear which consists in employing a grinding wheel which has a plane active face extending at right angles to its axis, engaging said wheel with the gear so that the axis of the wheel is inclined to the pitch plane of the gear, rotating the wheel on its axis and producing a relative rolling movement between the wheel and the gear while effecting a relative depthwise feed movement in time with the rolling movement between the wheel and gear about an axis perpendicular to the plane side of the wheel so that at one end of the rolling movement, in full depth position, the wheel will extend inside the root plane of the gear.

4. The method of grinding a gear which consists in employing a pair of plane-sided grinding wheels, engaging the wheels with the gear with their axes inclined to the pitch plane of the gear and angularly disposed to one another and so that the plane sides of the wheels engage opposite sides of spaced teeth of the gear, rotating the wheels on their respective axes and, while producing a relative rolling movement between the wheels and gear, feeding the wheels independently of one another depthwise into the gear in the directions of the plane sides of the wheels, said feed movements being so timed to the rolling motion that at one end of the rolling motion, one of the wheels extends inside the root plane of the gear and at the other end of the rolling motion, the other wheel extends inside said root plane.

5. In a machine for producing gears, a work support, a grinding wheel having a plane active face extending at right angles to its axis, means for positioning the wheel so that its plane side surface is inclined at other than a right angle to the pitch plane of the gear to be ground, means for rotating the wheel on its axis, means for producing a relative rolling movement between the wheel and work, and means for feeding the wheel depthwise into the work simultaneously and in time with said rolling movement in the direction of the plane side of the wheel so that at one end of the rolling movement, in full depth position, the wheel will extend inside the root plane of the gear.

6. In a machine for grinding gears, a work support, a grinding wheel having a plane active face perpendicular to its axis, a support for said wheel mounted to be swingable about an axis perpendicular to the plane side of the wheel, means for positioning the wheel so that its axis is inclined at other than a right angle to the pitch plane of the gear, means for rotating the wheel on its axis, means for producing a relative rolling movement between the wheel and gear, and

means for simultaneously effecting swinging movement of the wheel support in time with the rolling movement to effect a relative feed movement between the wheel and gear in the direction of tooth depth so that at one end of the rolling movement, in full depth position, the wheel will extend inside the root plane of the gear.

7. In a machine for grinding gears, a work support, a pair of grinding wheels having plane-sided active faces engageable, respectively, with opposite sides of spaced teeth of a gear with their axes angularly disposed to one another, means for rotating the wheels on their axes, means for producing a relative rolling movement between the wheels and the gear, and means for effecting depthwise feed movements of the wheels in the directions of their respective plane side surfaces as the gear and the wheels roll together, and means for correlating said feed movements to the rolling movement so that at one end of the rolling movement, one of the wheels will extend inside the root plane of the gear and at the other end of the rolling movement, the other wheel will extend inside said plane.

8. In a machine for grinding gears, a work support, a pair of grinding wheels having plane active faces engageable, respectively, with opposite sides of spaced teeth of a gear with their axes angularly disposed to one another, means for rotating the wheels on their axes, means for producing a relative rolling movement between the wheels and gear, means for automatically effecting relative depthwise feed movements between the wheels and gear in the direction of the respective plane side surfaces of the wheels as the gear and wheels roll together, means for periodically withdrawing said wheels, and means for indexing the gear during the periods of withdrawal.

9. In a machine for grinding gears, a work support, a pair of grinding wheels having plane active faces engageable, respectively, with opposite sides of spaced teeth of a gear with their axes angularly disposed to one another, supports for said wheels which are oscillatable, respectively, about axes parallel to the wheel axes, respectively, means for rotating the wheels on their axes, means for producing a relative rolling movement between the wheels and gear, and means for independently moving the wheel supports about their respective axes as the gear and wheels roll together to produce relative depthwise feed of the wheels into the gear.

10. In a machine for grinding gears, a work support, a pair of grinding wheels having plane active faces engageable, respectively, with opposite sides of spaced teeth of a gear with their axes angularly disposed to one another, means for rotating the wheels on their respective axes, means for producing relative rolling movements between the wheels and gear, means for effecting depthwise feed movement of each of the wheels into the gear in the direction of the plane side of the wheel during said rolling movements and in time therewith so that the two wheels grind, respectively, at opposite ends of each rolling movement to a greater depth than either grinds at the center of the rolling movement and so that in full depth position, the two wheels will extend, respectively, at opposite ends of the rolling movement inside the root plane of the gear, means for relatively feeding the gear depthwise into the wheels on successive rolling movements until full depth position is reached and means for then relatively withdrawing the wheels from en-

gagement with the gear to permit indexing the gear.

11. In a machine for grinding gears, a work support, a pair of grinding wheels having plane active faces engageable, respectively, with opposite sides of spaced teeth of a gear with their axes angularly disposed to one another, supports for said wheels which are oscillatable, respectively, about axes parallel to the wheel axes, means for rotating the wheels, means for producing relative rolling movements between the wheels and gear, means for oscillating said wheel supports independently of one another during the roll, means for oscillating said supports together to move the wheels into and out of operative position and means for indexing the work when the wheels are out of operative position.

12. In a machine for grinding gears, a work support, a pair of grinding wheels having plane

active faces engageable, respectively, with opposite sides of spaced teeth of a gear with their axes angularly disposed to one another, supports for said wheels which are oscillatable, respectively, about axes parallel to the wheel axes, means for rotating the wheels, means for producing relative rolling movements between the wheels and gear, means for oscillating said wheel supports independently of one another during the roll, means for oscillating said supports together to move the wheels into and out of operative position, said last-named means being so timed to the rolling movement that a plurality of rolling movements take place while the wheels remain in operative position and means for indexing the work when the wheels are out of operative position.

ERNEST WILDHABER.