

[54] GEAR FORMING

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[58] **Field of Search**.....72/102, 107, 108, 109, 88,
72/68, 126; 29/159.2

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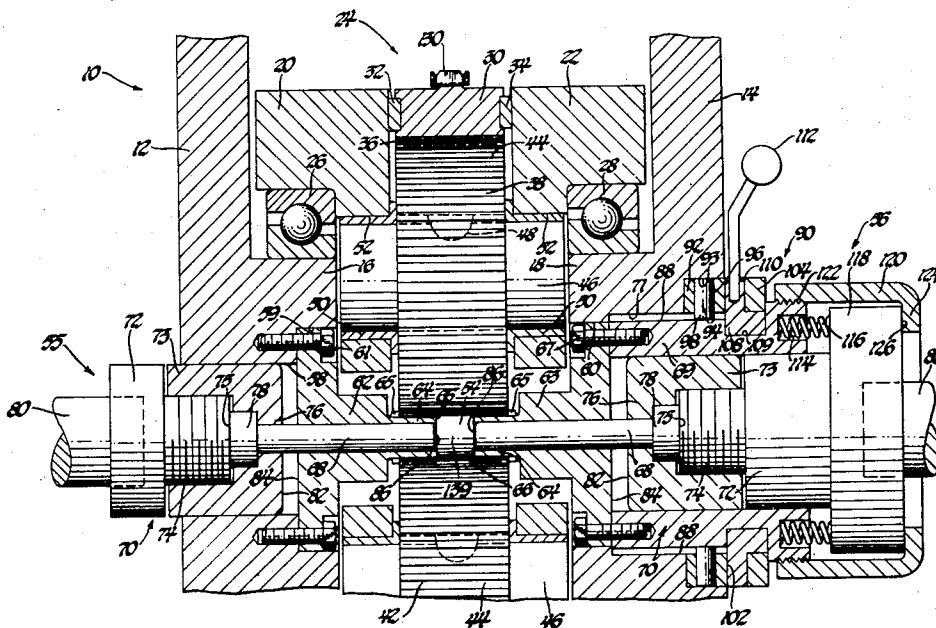
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[57]

ABSTRACT

A mechanism and method for pressure-forming teeth on the periphery of a cylindrical workpiece, the mechanism including support members for a planetary gear set wherein the planet pinions serve as toothed forming rolls driven by the outer ring gear, and a workpiece on which gear teeth are to be formed serves as the sun member mounted at the center of rotation of the toothed forming rolls. A punch assembly is mounted adjacent each end face of the workpiece, each punch assembly including (1) a punch guide abutting against a face of the workpiece to enable the latter to serve as a reaction member and to prevent any outward axial displacement of the metal of the workpiece, (2) a punch slidably mounted within the punch guide, and (3) cylinder means for slidably moving the punches through the punch guides into pressure contact with the end faces of the workpiece to cause the metal of the workpiece to flow radially outwardly to conform the periphery thereof to the spaces between the teeth of the rotating forming rolls. In lieu of the planetary gear set, a pair of parallel rack bars, with the workpiece mounted in between, may be employed in conjunction with the punch assemblies to form the gear teeth on the workpiece.

7 Claims, 7 Drawing Figures



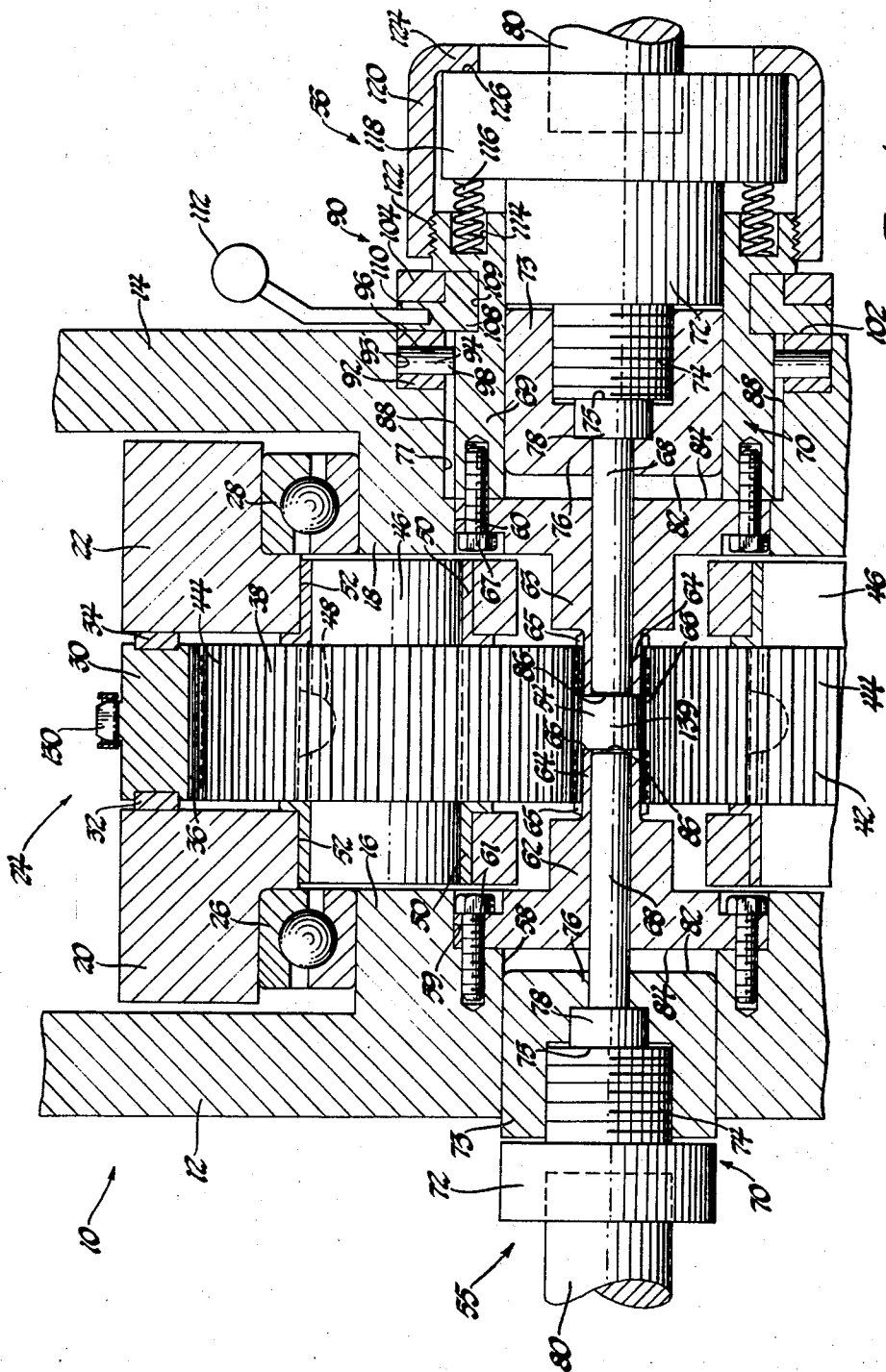


Fig. 1

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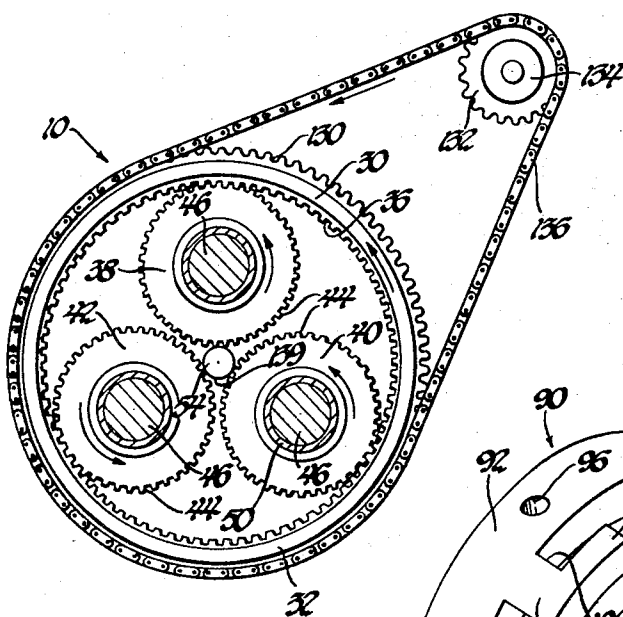


Fig. 2

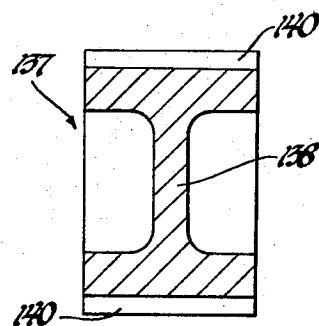


Fig. 4

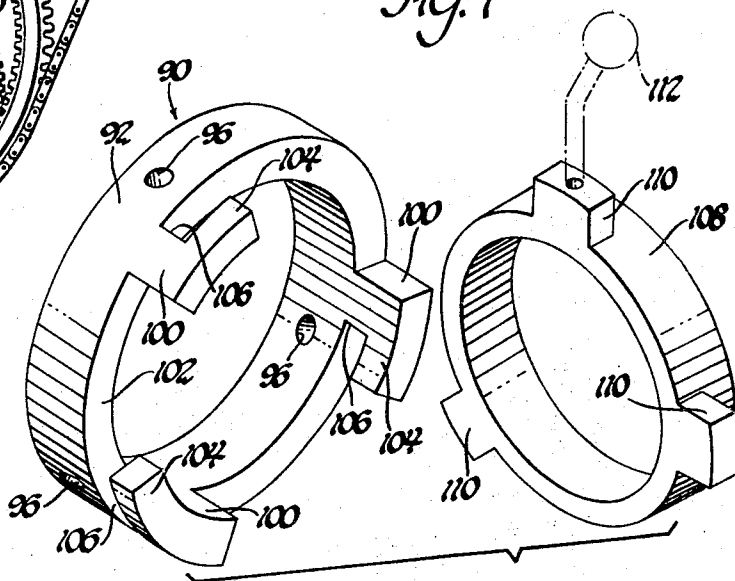


Fig. 3

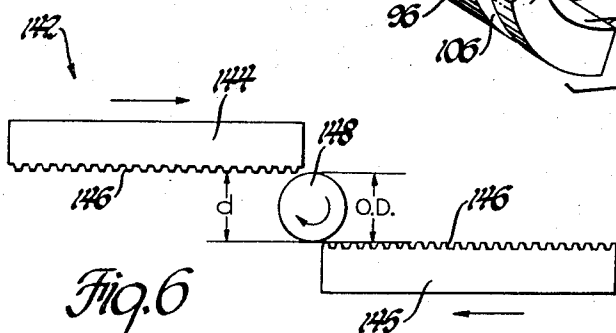


Fig. 6

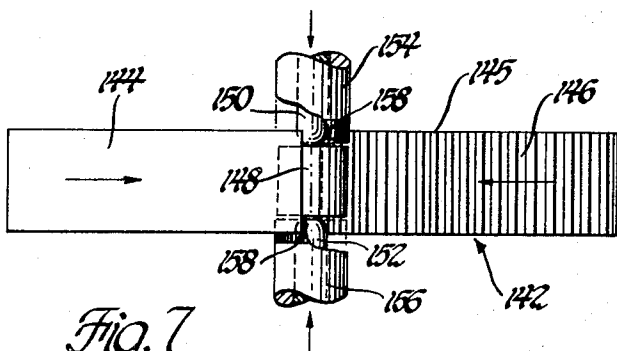


Fig. 7

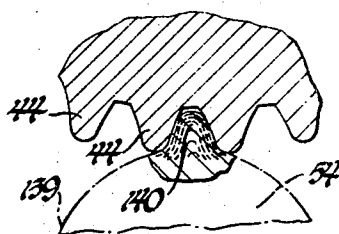


Fig. 5

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GEAR FORMING

This invention relates generally to the manufacture of gears and, more specifically, to the generation of external gear teeth by pressure-forming.

Heretofore it has been customary in the forming of gear teeth to employ either a prehobbed gear shape or a cylindrical blank and then, either by means of slidably mounted rolling dies or rack bars, to form the metal such that the pitch diameter of the finished part is the same as the original cylindrical blank diameter, i.e., the total volume of metal removed during the cold forming process between the pitch circle and the root circle is equal to the total volume of metal included between the pitch circle and the finished gear outer circumference.

It is an object of this invention to provide improved means for pressure-forming improved gears wherein the metal-flow characteristics approach those of a forging operation as opposed to those of a rolling operation.

Another object of the invention is to provide means for forming helical and/or spur gears wherein rolling dies or rack bars are employed in conjunction with suitable punches to produce continuous metal flow-line characteristics.

A further object of the invention is to provide means for forming gears wherein the displaced metal is caused to flow primarily in only one general direction, i.e., radially outwardly.

Still another object of the invention is to provide means for pressure-forming gears wherein the pitch diameter of the finished part is greater than the original cylindrical blank diameter, the latter being the same as the root diameter of the finished gear.

A still further object of the invention is to provide means including slidably mounted rolling dies or rack bars oppositely disposed adjacent the outer periphery of a cylindrical gear blank, and transversely slidable punches oppositely disposed adjacent the end faces of the gear blank, wherein the converging punches force the metal of the gear blank to move radially outwardly into the contours formed on the dies or racks, the latter primarily serving to direct the flow of the metal to form the desired shape.

These and other objects and advantages of the invention will become more apparent when reference is made to the following description and accompanying drawings, wherein:

FIG. 1 is a cross-sectional view of a rolling die arrangement embodying the invention;

FIG. 2 is a partial cross-sectional view of the planetary unit portion of FIG. 1, as if FIG. 1 were a full round view, and including an input means;

FIG. 3 is a perspective view of portions of the FIG. 1 structure;

FIG. 4 is a fragmentary view of a portion of a gear formed by the invention;

FIG. 5 is a cross-sectional view of a gear formed by the invention; and

FIGS. 6 and 7 are side and top views, respectively, of another embodiment of the invention.

Referring now to the drawings in greater detail, FIGS. 1 and 2 illustrate a pressure-forming mechanism 10 including oppositely disposed, fixed flat support members 12 and 14. Laterally extending collars 16 and 18 are formed on the support members 12 and 14,

respectively, such that the collars 16 and 18 extend toward one another and are axially aligned.

Carrier members 20 and 22 of a planetary gear set 24 are rotatably mounted on bearings 26 and 28 between the support members 12 and 14 around the collars 16 and 18, respectively. An outer ring gear 30 is mounted between the carrier members 20 and 22. Bronze thrust bearings 32 and 34 are mounted between the faces of the outer ring gear 30 and the carrier members 20 and 22, respectively. Gear teeth 36 are formed around the inner surface of the outer ring gear 30. Three (3) forming rolls 38, 40, and 42 (FIG. 2), each having external gear teeth 44 formed thereon, are mounted within the outer ring gear 30, the external teeth 44 meshing with the internal teeth 36 of the outer ring gear 30. The gear teeth 36 and 44 may be either of the spur or helix type.

Each of the forming rolls 38, 40, and 42 is secured to respective forming roll shafts 46 by any convenient means, such as a key 48. Each of the shafts 46 is supported at its ends on a pair of bronze bushings 50 mounted in aligned pockets 52 formed in the carrier members 20 and 22. A workpiece 54, consisting originally of a cylindrical blank, serves as a sun member of the planetary gear set 24.

Left- and right-hand punch assemblies 55 and 56 are mounted in axially aligned openings 58 and 60 formed through the collars 16 and 18, respectively, the opening 60 being larger than the opening 58, as will be explained. The punch assemblies 55 and 56 include punch guides 62 and 63, respectively. The left-hand punch assembly 55 is mounted in a recess 59 formed in the opening 58 and secured therein by bolts 61. The punch guide 63 is slidably mounted in the opening 60 and secured by bolts 67 to a sleeve member 69 which is mounted in a counterbore 71 formed in the opening 60. Each punch guide 62 and 63 includes a small diameter body portion 64 having external spline- or teeth-like members 65 formed thereon, the external members 65 meshing with the external teeth 44 formed on the forming rolls 38, 40, and 42. As will be seen, the punch guides 62 and 63 serve as the reaction members in conjunction with the workpiece 54, the inner end face 66 of each of the punch guides 62 and 63 abutting against the radially outer portions of the end faces of the workpiece 54.

A punch 68 is slidably mounted within each of the punch guides 62 and 63 along the axis of the pressure-forming mechanism 10. Each punch 68 is driven by a punch driver 70, each punch driver 70 including members 72 and 73 threadedly interconnected by threads 74. The member 72 abuts against the end face 75 of the punch 68, and the member 73 includes an internal flange 76 which is positioned adjacent an external flange 78 formed on the punch 68 opposite the end face 75 for confining the flange 78 therebetween for reciprocal movement of the punch 68 with the punch driver 70. Thus each member 72 serves to slide the respective punch 68 inwardly in response to the forward stroke of a hydraulic cylinder, represented generally at 80, while the internal flange 76 of the member 73 causes the punch 68 to retract on the rearward stroke of the respective hydraulic cylinder 80. When the hydraulic cylinder 80 is fully retracted, the maximum allowable stroke of each punch 68 and the punch driver 70 is seen to be the distance between the

front face 82 of the member 73 and the rear face 84 of the adjacent punch guide 62 or 63. The inner end face 86 of each of the punches 68 may be pressed into the end faces of the workpiece 54 by extending through the punch guides 62 and 63, as will be described, while the end faces 66 of the punch guides 62 and 63 abut against the radially outer portions of the respective faces of the workpiece 54.

The right-hand punch guide 63 may be withdrawn axially from its meshing engagement with the forming rolls 38, 40, and 42 far enough to permit the workpiece 54 to be inserted into the center of rotation of the pressure forming mechanism 10 and removed therefrom as a finished part. As will be explained, this is facilitated by the formation of one or more grooves 88 along the outer periphery of the sleeve member 69 adjacent the counterbore 71 of the support arm 14. A locking bolt 90, better seen in FIG. 3, includes a ring portion 92 which is secured in any suitable manner, such as by being press-fitted in a recess 93 formed in the support arm 14, the ring portion 92 being mounted around the sleeve member 69. A pin 94 is inserted through a radially extending opening 96 formed in the ring portion 92. The inner end 98 of the pin 94 extends into the groove 88, the latter having the same lead as the splines 65. A plurality of locking tabs 100 (FIG. 3) are formed on a face 102 of the ring portion 92. A laterally extending lip or flange 104 is formed on each locking tab 100, providing a controlled space 106 between each flange 104 and the face 102 of the ring portion 92. A locking ring 108 (FIGS. 1 and 3) is positioned adjacent the face 102 of the locking bolt 90 in an annular groove 109 (FIG. 1) formed in the sleeve member 69 and includes a plurality of radially extending projections 110 (FIG. 3) which may be rotated into and out of the respective spaces 106 by any convenient means, such as a handle 112, extending from one of the projections 110.

A plurality of axially extending pockets 114 are formed in the outer face of the sleeve member 69. A spring 116 is positioned in each of the pockets 114 adjacent a collar 118 formed on the outer end of the punch driver member 72. A sleeve 120 is threadedly secured by threads 122 to the sleeve member 69. A radially inwardly extending flange 124 is formed on the sleeve 120 adjacent the outer face 126 of the collar 118 of the punch driver member 72. The grooves 88 along the outer periphery of the sleeve member 69 serve as lead guides suitable for re-meshing the forming rolls 38, 40, and 42 with the splines 65 once another workpiece 54 has been inserted against the end face 66 of the left-hand punch guide 62.

Sprocket teeth 130 are formed on the outer periphery of the outer ring gear 30. A sprocket 132 (FIG. 2), actuated by a suitable electric motor, represented generally at 134, drives a chain 136 which is mounted around the outer ring gear 30 on the sprocket teeth 130 for driving the outer ring gear 30.

In operation, it may be noted in FIG. 2 that, once the workpiece 54 has been inserted against the end face 66 of the fixed punch guide 62 and the movable punch guide 63 moved into contact with the workpiece 54, with the outer ring gear 30 being driven by the chain 136 in a counterclockwise direction, each of the forming rolls 38, 40, and 42, as well as the carrier members 20 and 22 (FIG. 1), will likewise be driven in a counter-

clockwise direction, causing the forming rolls 38, 40, and 42 to "walk around" the outside surface of the workpiece 54 and the splines 65 of the punch guides 62 and 63, within the internal gear teeth 36 of the outer ring gear 30. While the above rotational action is taking place, the workpiece 54 remains stationary by virtue of its being contacted at each of its side faces by the respective oppositely disposed ends 86 and 66 of the nonrotating punches 68 and the punch guides 62 and 63.

When the punches 68 are moved toward one another (FIG. 1) by the respective hydraulic cylinders 80, the sides of the workpiece 54 are pushed inwardly thereby (FIG. 4), causing the metal which is thus displaced to flow radially outwardly, the outer surface of the workpiece 54 being progressively caused to assume a gear tooth shape (FIG. 5), as determined by the rotating forming rolls 38, 40, and 42. The end faces 66 of the punch guides 62 and 63 abutting against the adjacent face areas of the workpiece 54 prevent any axial extrusion of the metal while the metal is caused to flow radially outwardly therepast. There results a completely formed gear 137 (FIG. 4) having a central hub or web 138 of a predetermined thickness.

It may be noted in FIG. 5 that the original outer surface 139 of the original workpiece 54 forms the root diameter of the newly formed finished gear teeth 140. Thus it is apparent that the displaced metal flows in only a substantially radially outward direction. The pitch diameter of the finished gear 137 is thus greater than the outside diameter of the original workpiece 54.

At this point it may be realized that since all the displaced metal moves only outwardly into the cavities provided by the teeth 44 of the rotating forming rolls 38, 40, and 42, there results continuous flow-lines, as opposed to noncontinuous flow-lines inherent in those processes where gears are formed by rolling dies which contact a workpiece at its outer periphery and move metal therefrom in both radial directions such that the original outer periphery becomes substantially the pitch circle of the finished piece. In the latter operation, as the rolling dies converge on a workpiece, metal is necessarily raised or pushed radially outwardly adjacent both contacting edges of each tooth, increasing the possibility of a "cold shut" when the two raised edges converge to form the crown of each tooth.

Consider now the right-hand portion of FIG. 1, and assume the end face 86 of the punch 68 being embedded in the workpiece 54 adjacent the web 138 (FIG. 4), having force the metal of the workpiece 54 to flow radially outwardly, as explained above. The cylinder 80 is now pressurized on the opposite end, thereby being caused to move rightwardly in FIG. 1, pulling the punch 68 out of the workpiece 54 until the end face 86 of the punch 68 becomes radially aligned with the end face 66 of the punch guide 63 and the face 126 of the collar member 118 once again abuts against the flange 124 of the sleeve member 120 and is retained thereagainst by the springs 116. At this point, the locking ring 108 is rotated by the handle 112 manually or by other suitable automatic means, moving the projections 110 out of the space 106 between the flanges 104 and the ring portion 92, thereby freeing the locking ring 108, permitting full rightward (FIG. 1) retraction of the cylinder 80 and the associated punch

68, carrying the locking ring 108, the sleeve member 120, and the punch guide assembly 56 along therewith. During the retraction process, the groove 88 of sleeve member 69 will move past the end 98 of the pin 94. It may be realized that the groove 88 may be straight for spur gear formation and helical for helical gear formation, thus conforming to the type teeth formed on the forming rolls 38, 40, and 42. Once retracted a predetermined distance, depending on the overall width of the now finished gear 137, the finished gear 137 may be manually removed and a new rough workpiece 54 inserted in position against the inner end 86 of the left-hand (FIG. 1) punch 68 and the inner face 66 of the left-hand punch guide 62, ready for the return movement of the right-hand punch guide 63 and the punch 68 under the reversed action of the right-hand cylinder 80.

An alternate embodiment is illustrated in FIGS. 6 and 7. The pressure-forming mechanism 142 illustrated therein includes a pair of parallel and oppositely reciprocating rack bars 144 and 145, each having similar gear teeth 146 formed thereon. The rack bars 144 and 145 are spaced apart a distance "d" equal to the outside diameter "O.D." of a cylindrical workpiece 148 (FIG. 6). Punches 150 and 152 (FIG. 7) are located adjacent opposite end faces of the workpiece 148 for reciprocal motion toward and away from one another, transverse to the reciprocal motion of the rack bars 144 and 145. The punches 150 and 152 may be guided by respective punch guides 154 and 156.

It may be realized that the principle of operation for the pressure-forming mechanism 142 is similar to that of the pressure-forming mechanism 10, in that the original O.D. of the workpiece 148 ultimately becomes the root diameter of a finished gear after the punches 150 and 152 have compressed the end faces of the workpiece 148, causing the metal thereof to flow radially outwardly, filling the space between the gear teeth 146 formed on the rack bars 144 and 145, as the rack bars 144 and 145 reciprocate across one another. In the pressure-forming mechanism 142, the workpiece 148 is rotated intermediate the rack bars 144 and 145 by the gear teeth 146 while similar gear teeth are formed on the outer periphery of the rotating workpiece 148.

The teeth 146 may be either of the spur- or helical-type. If the workpiece 148 is narrower than the width of the rack bars 144 and 145, corresponding spur or helical teeth 158 are formed on the outer peripheries of the forward end portions of each of the punch guides 154 and 156 to mesh with the teeth 146 of the rack bars 144 and 145 and be rotated thereby.

It should now be apparent that the invention provides improved means for forming either spur or helical gears without the possible "cold shut" disadvantage of a rolling operation wherein the metal is displaced from radially within the pitch circle to radially outwardly thereof with raised edge portions being inherent at the outer periphery of each tooth. The invention has the advantage of metal flow-line characteristics similar to those of a forging operation while precluding the possibility of any attendant detrimental effect resulting from the build-up of heat in a conventional closed die forging, as a result of the above-described operation and the size of the forming rolls 38, 40, and 42.

While but two embodiments of the invention have been shown and described, other modifications thereof are possible.

I claim:

1. A mechanism for pressure-forming teeth on the periphery of a cylindrical workpiece, said mechanism comprising oppositely disposed fixed support members; a planetary gear set including carrier members rotatably mounted on said fixed support members, an outer ring gear rotatably mounted intermediate said carrier members, a plurality of exterior toothed forming rolls meshing with said outer ring gear and mounted on a plurality of equally spaced forming roll shafts rotatably supported at the ends thereof in openings formed in said carrier members, a non-rotating workpiece mounted at the center of rotation of said plurality of forming rolls; means for rotating said outer ring gear; a punch assembly mounted adjacent each end face of said workpiece, each of said punch assemblies including a punch guide secured to each of said fixed support members and abutting against a face of said workpiece to serve as the reaction member for said planetary gear set, a punch slidably mounted within each of said punch guides, means for slidably moving each of said punches into and out of pressure-contact with said end faces of said workpiece as required to cause the metal of said workpiece to flow radially outwardly to conform the periphery thereof to said exterior toothed forming rolls, and locking means for permitting one of said punch guides to be slidably removed from one of said fixed support members to permit the removal of a finished workpiece from against the face of the other of said punch guides and the insertion of a new workpiece thereagainst.

2. A mechanism for pressure-forming teeth on the periphery of a cylindrical workpiece, said mechanism comprising oppositely disposed fixed support members having axially aligned support collars formed thereon; a planetary gear set including carrier members rotatably mounted on said fixed support collars, an outer ring gear rotatably mounted intermediate said carrier members, thrust bearings mounted between the end faces of said outer ring gear and the adjacent sides of said carrier members, a plurality of exterior toothed forming rolls meshing with said outer ring gear and mounted on a plurality of equally spaced forming roll shafts rotatably supported at the ends thereof in openings formed in said carrier members, a nonrotating workpiece mounted at the center of rotation of said plurality of forming rolls and having an outside diameter equal to the diameter of the circle formed by the outer edges of said rotating forming rolls around said center of rotation; means for rotating said outer ring gear on said thrust bearings; a punch assembly mounted adjacent each end face of said workpiece, each of said punch assemblies including a punch guide secured to each of said fixed support members and having an end face thereof abutting against a face of said workpiece to serve as the reaction member for said planetary gear set, a plurality of splines formed on the outer periphery of each of said punch guides adjacent said respective end faces thereof for meshing with said exterior toothed forming rolls, a punch slidably mounted within each of said punch guides, and means for slidably moving each of said punches into pressure-contact with said

end faces of said workpiece as required to cause the metal of said workpiece to flow radially outwardly to conform the periphery thereof to said exterior toothed forming rolls, the finished gear root diameter being the same as said original workpiece outside diameter.

3. A mechanism for pressure-forming teeth on the periphery of a cylindrical workpiece, said mechanism comprising oppositely disposed parallel fixed support members, a pair of rack bars slidably mounted on said fixed support members, means for concurrently reciprocally sliding said pair of rack bars in opposite directions with respect to one another but not toward or away from one another, a plurality of teeth formed on adjacent surfaces of said pair of rack bars, a disc-shaped workpiece mounted intermediate said pair of rack bars with the periphery thereof in rolling contact with the crowns of said oppositely disposed teeth on said rack bars, a punch assembly mounted adjacent each end face of said workpiece, said punch assembly including a slidably mounted rotatable punch, and means for slidably moving said rotatable punch into pressure-contact with the end faces of said workpiece to cause the metal of said workpiece to flow radially outwardly to conform the outer periphery thereof to said adjacent teeth of said reciprocating rack bars as said workpiece is caused to rotate by and between said reciprocating rack bars.

4. A method of forming gear teeth on a workpiece, said method comprising the following steps:

- a. forming gear teeth on adjacent sides of each of a pair of parallel reciprocable rack bars spaced a predetermined constant distance apart;
- b. placing said workpiece intermediate said pair of rack bars, said workpiece having an outside diameter equal to the distance between the crowns of said oppositely disposed gear teeth;
- c. contacting the end faces of said workpiece by a pair of slidably mounted rotatable punches;
- d. moving said rack bars in opposite longitudinal directions toward and past one another while forcing said pair of punches into said end faces of said workpiece for displacing the metal of said workpiece radially outwardly into the spaces between said gear teeth on said rack bars as said workpiece is caused to rotate by and between said oppositely moving rack bars; and
- e. retracting at least one of said punches and removing the finished gear formed from said workpiece.

5. The mechanism described in claim 1, wherein said locking means includes a ring portion secured to said one of said fixed support members, a sleeve member slidably mounted within said ring portion, a first plurality of locking tabs formed on a face of said ring por-

tion, an annular groove formed in the outer periphery of said sleeve member, a locking ring rotatably mounted in said annular groove adjacent said ring portion, a second plurality of locking tabs formed on a face of said locking ring for interconnection with said first plurality of locking tabs.

6. The mechanism described in claim 5, and a plurality of pins mounted in said ring portion and extending radially inwardly from the inner surface thereof, a plurality of grooves formed on the outer surface of said one of said punch guides at an intermediate portion thereof and slidably along said respective pins, and a plurality of splines formed on the outer periphery of said punch guides adjacent the end thereof abutting against said face of said workpiece for meshing with the teeth of said exterior toothed forming rolls, both said splines and said grooves having the same shape as said teeth of said exterior toothed forming rolls.

7. A method of forming gear teeth on a workpiece, said method comprising the following steps:

- a. forming gear teeth on the inside surface of an outer ring;
- b. forming gear teeth on the outer periphery of each of a plurality of forming rolls suitable for meshing with said teeth on said outer ring;
- c. forming splines on the outer periphery of a pair of oppositely disposed punch guides suitable for meshing with said gear teeth on the outer periphery of each of said forming rolls, one of said punch guides being fixed axially and the other of said punch guides being movable axially;
- d. forming an axial passage through each of said punch guides;
- e. mounting said workpiece at the center of rotation of said plurality of forming rolls against the end of said fixed punch guide, said workpiece having an outside diameter equal to the diameter of the circle formed by the outer edges of said rotating forming rolls around said center of rotation;
- f. contacting the end faces of said workpiece by the end of said axially movable punch guide;
- g. slidably mounting a pair of punches through said respective axial passages of said punch guides and contacting said end faces of said workpiece;
- h. rotating said outer ring;
- i. forcing said pair of punches into the end faces of said workpiece for causing the metal of said workpiece to be displaced radially outwardly into the spaces between said gear teeth of said rotating forming rolls; and
- j. retracting said axially movable punch guide and removing the finished gear formed from said workpiece.

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