United States Patent

Anderson

[15] **3,672,203**

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[54] TOOTH FORMING TOOL

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[52] **U.S. Cl.** **72/469**
[51] **Int. Cl.** **B21h 5/02**
[58] **Field of Search** 72/88, 90, 469

[56] **References Cited**

UNITED STATES PATENTS

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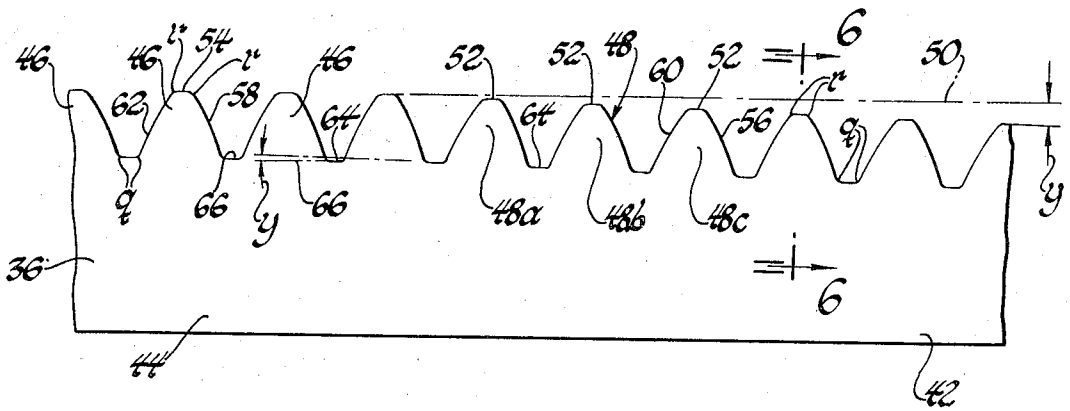
[57] **ABSTRACT**

A tool for pressure forming teeth on the periphery of a cylindrical workpiece comprising a body having a leading end and a trailing end with a front portion extending rearwardly from the leading end and a rear portion extending from the front portion to the trailing end. A plurality of identical teeth are provided on the rear portion, each of which has a configuration fully conjugate to the configuration of the teeth to be formed on the workpiece. A plurality of teeth are formed on the front portion, the tips of which are spaced from the plane of the tips of the teeth of the rear portion at progressively increasing distances from the juncture of the front and rear portions to the leading end. Each tooth on the front portion is congruent with the teeth on the rear portion from the tips of the teeth of the rear portion toward the root thereof for a distance corresponding to the height of the respective front tooth. In one arrangement, the front teeth are each inclined with respect to the rear teeth and are otherwise of identical size to the rear teeth. In another arrangement, the body has a root line common to both the front and rear portions, and the front teeth are each of progressively decreasing height above the root line from the juncture of the front and rear portions to the leading end of the body.

12 Claims, 9 Drawing Figures



PRIOR ART

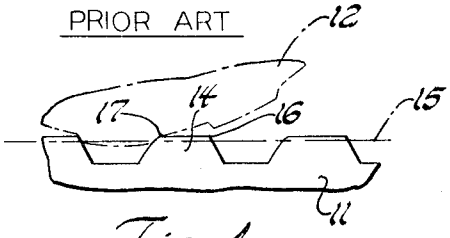


Fig. 1

PRIOR ART

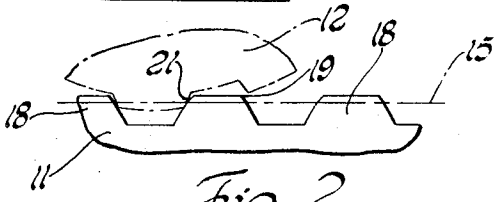


Fig. 2

PRIOR ART

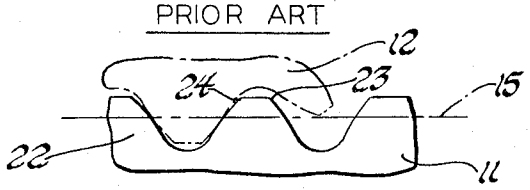


Fig. 3

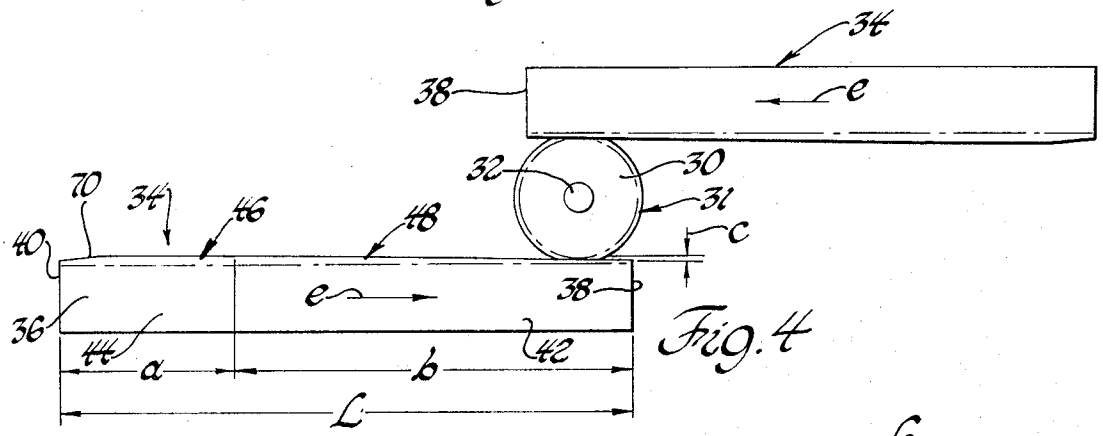


Fig. 4

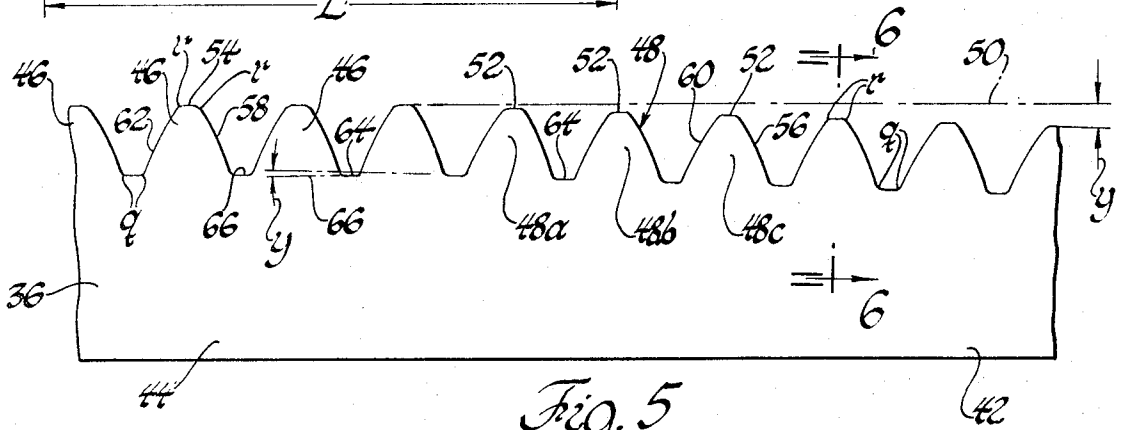


Fig. 5

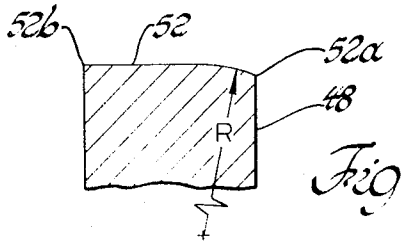


Fig. 6

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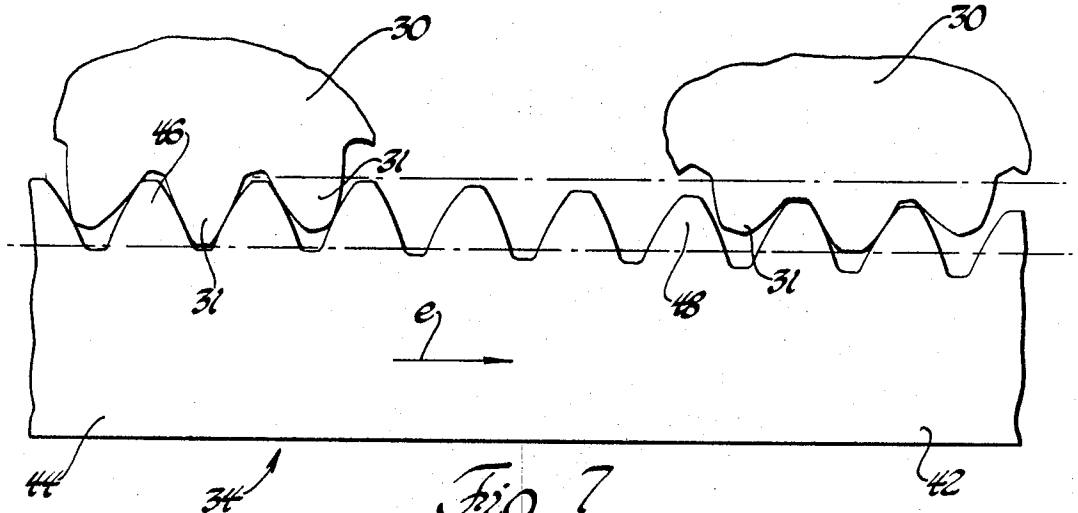

Fig. 7

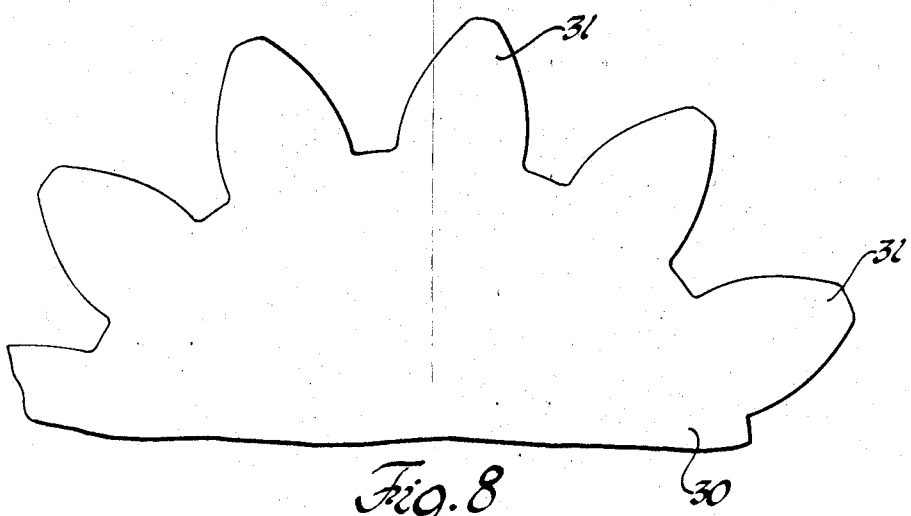

Fig. 8

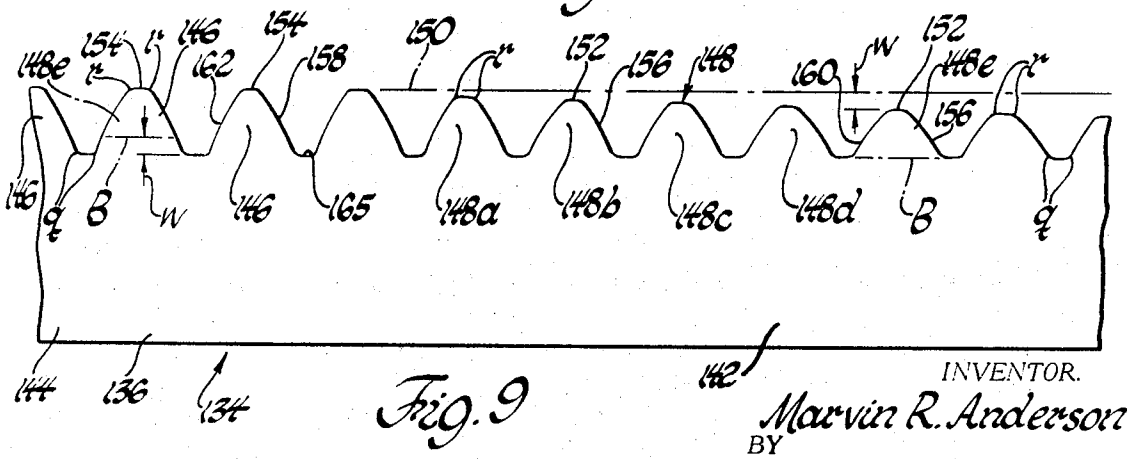

Fig. 9

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TOOTH FORMING TOOL

This invention relates generally to tools for forming splines, gear teeth, serrations and the like, and is particularly concerned with tools for cold forming, or pressure forming teeth on the periphery of a cylindrical workpiece by rotating the workpiece between a pair of reciprocating rack bodies.

Prior art tooth forming tools wherein a cylindrical workpiece is formed with teeth by rotating the workpiece between reciprocating rack tools includes the type shown in U.S. Pat. Nos. 2,994,237 and 3,015,243 wherein the tooth forming tool is provided with three groups of teeth. One group of teeth on the leading end of the tooth forming tool includes teeth of reduced height and a sharp leading edge. A second group of teeth are provided which are of reduced height with respect to the conjugate teeth although being slightly greater in height than the group of teeth adjacent the leading teeth. The third group of teeth are of full height and are fully conjugate to the teeth to be formed on the workpiece.

There are several problems encountered with the prior art devices as discussed in the preceding paragraph. First, to provide the sharp leading edges on the teeth at the leading end of the tool with the full radii on the trailing edges of such teeth requires a great amount of skill on the part of the individual operator of the grinding machine. Secondly, the sharp leading edges of the partially formed teeth on the leading end of the tool tends to shear the metal of the workpiece during the pressure forming operation. Thirdly, during the cold forming operation of the workpiece, the partially formed teeth at the leading end of the tool are wide at the tip, and the tips of the teeth get progressively narrower as the tool advances over the workpiece so that the tips bear the full pressure at least upon initial contact with the workpiece. The concentration of pressure aggravates the tendency of the teeth to shear the metal of the workpiece.

The teeth at the leading end of the tool are reduced in height so that the space between the tips of the teeth of the opposed reciprocating rack tool progressively decrease as the tools advance relative to the workpiece so that the depth of penetration of the rack teeth gradually increases to displace the material of the workpiece. However, since the tips of the teeth at the leading end of the tool are wider and progressively decrease in width as the tool advances relative to the workpiece, the forming pressure is always concentrated at the tip of the teeth at least until the teeth penetrate fully into the workpiece.

An object of this invention is to provide a tooth forming rack tool wherein the configuration of the teeth on the tool is such that the pressure is distributed uniformly over the surface of each tooth of the tool as it is forced into the material of the workpiece.

A further object is to provide a tool for pressure forming teeth on the periphery of a cylindrical workpiece including a rear portion on the tool having teeth that are fully conjugate to the teeth to be formed on the workpiece and which are to penetrate the workpiece to full depth, with a front portion having teeth thereon, the tips of which are spaced from the plane of the tips of the teeth on the rear portion at progressively increasing distances toward the leading end, each tooth on said front portion being congruent with the teeth on the rear portion from the tips of the teeth on the rear portion toward the root thereof a distance corresponding to the height of the respective front tooth.

A further object is to provide a tool for pressure forming teeth on the periphery of a cylindrical workpiece comprising a body having a front portion and a rear portion with a plurality of identical teeth on the rear portion each having a configuration fully conjugate to the configuration of the teeth to be formed on the workpiece, and a plurality of teeth on the front portion, each of which is identical with the teeth on the rear portion, but in which the tips thereof are spaced at progressively increasing distances from the plane of the tips of the teeth on the rear portion toward the leading end of the tool so that the space between the tips of the teeth of opposed racks progressively decreases as the tools advance relative to the workpiece.

A still further object is to provide a tool for pressure forming teeth on the periphery of a cylindrical workpiece including a body having a front portion and a rear portion with a plurality of identical teeth on the rear portion having a configuration fully conjugate to the configuration of the teeth to be formed on the workpiece; and a plurality of teeth on the front portion, the tips of which are spaced from the plane of the tips of the teeth on the rear portion at progressively increasing distances toward the leading end, and wherein the body has a root line common to the front and rear portions, the teeth on the front portion projecting from the root line at heights progressively decreasing toward the leading line of the body, the teeth on the front portion being congruent with the corresponding portion of the teeth on the rear portion from the tips thereof toward the root.

In carrying out the foregoing, and other objects, a tool according to the present invention includes a body having a leading end and a trailing end with a front portion extending rearwardly from the leading end and a rear portion extending from the front portion to the trailing end. A plurality of identical teeth are formed on the rear portion, each of which has a configuration fully conjugate to the configuration of the teeth to be formed on the workpiece. A plurality of teeth are provided on the front portion, and the tips of the teeth on the front portion are spaced from the plane of the tips of the teeth of the rear portion at progressively increasing distances toward the leading end so that the space between the tips of the teeth of opposed reciprocating rack tools progressively decreases as the tools advance relative to the workpiece so that the depth of penetration of the teeth of the tools gradually increases to displace the material of the workpiece. The tips of the teeth of the front and rear portions all have the same width, and each tooth on the front portion of the tool is congruent with the teeth on the rear portion from the tips of the teeth of the rear portion toward the root thereof a distance corresponding to the height of the respective front tooth.

In one embodiment of the invention, the teeth along the front portion of the tool are each inclined with respect to the teeth of the rear portion due to the taper of the front portion. Each tooth of the front portion is of the same height as the teeth of the rear portion, and hence is of a configuration fully conjugate to the configuration of the teeth to be formed on the workpiece. The tips of all of the teeth on the tool are of the same width so that portions of the leading and trailing flanks of these teeth engage the workpiece simultaneously with the tips to distribute the pressure over the entire surface of the tooth that is engaged with the workpiece. The root line of the teeth of the front portion in this embodiment is inclined toward the leading end with respect to the root line of the teeth of the rear portion.

In another embodiment, the body has a root line which is common to both the front and rear portions, but the teeth on the front portion project from the root line at heights progressively decreasing toward the leading end of the body. However, since the teeth at the front portion are fully congruent with the teeth on the rear portion from the tips of the rear portion towards the root thereof a distance corresponding to the height of the respective front tooth, the pressure is uniformly applied over all surfaces of the teeth that penetrate the material of the workpiece. The width of the tips of all of the teeth on the tool is the same, and the juncture of the leading and trailing flanks of each of the teeth with the tips thereof has the same predetermined radius. Similarly, the juncture of the leading and trailing flanks of each of the teeth with the associated root line has the same predetermined radius.

Other objects, advantages and features of the invention will become apparent from the following description taken in connection with the accompanying drawings in which:

FIGS. 1, 2 and 3 are fragmentary elevational views of the teeth of prior art tooth forming tools;

FIG. 4 is an elevational view of apparatus having tooth forming tools embodying the present invention;

FIG. 5 is an enlarged fragmentary elevational view of one of the rack tools of FIG. 4;

FIG. 6 is a sectional view taken on line 6—6 of FIG. 5;

FIG. 7 is a view similar to FIG. 5 illustrating the workpiece at different positions along the tool;

FIG. 8 is a partial elevational view of a finished workpiece; and

FIG. 9 is a fragmentary elevational view of a tool embodying the invention in another form.

A rack tool of the type with which the present invention is concerned is generally employed for forming teeth in a cylindrical workpiece mounted on a stationary pivot between a pair of opposed rack tools. The tools are driven in opposite directions such that the teeth engage the workpiece at diametrically opposed locations to cause the workpiece to rotate and the teeth of the tool to progressively penetrate the material of the workpiece and form teeth in the workpiece by displacing the metal of the workpiece. FIGS. 1, 2 and 3 illustrate the configuration of the teeth of a prior art tool of this type at the leading end, an intermediate portion, and at the rear end of the tool, respectively.

FIG. 1 illustrates teeth 14 on a tool 11 located at the leading end of the tool. The teeth 14 project only slightly above a pitch line 15 and are formed with sharp leading edges 16 and rounded trailing edges 17.

FIG. 2 illustrates the configuration of the teeth of the same tool 11 engaged by the workpiece 12 as the tool advances from the leading end teeth shown in FIG. 1. The teeth 18 in FIG. 2 have an increased height with respect to the pitch line 15 over the teeth 14 of FIG. 1, and have relatively sharp leading edges 19 and rounded trailing edges 21.

As the tool 11 advances from the position of FIG. 2 relative to the workpiece 12, teeth 22 engage the workpiece 12 which are of constant height and are fully conjugate to the teeth to be formed on the workpiece 12. The teeth 22 have leading and trailing edges 23 and 24 at the juncture of the leading and trailing flanks with the tip thereof having substantially the same radii.

In the teeth of the prior art tool 11 of FIGS. 1, 2 and 3, the width of the tips of the teeth decrease progressively as the tool advances relative to the workpiece from the FIG. 1 position to the FIG. 3 position. Consequently, the pressure is concentrated at the tips of the teeth, particularly in FIGS. 1 and 2, as the teeth engage the workpiece and begin to penetrate the material of the workpiece. Furthermore, the sharp leading edges 16 and 19 of the teeth 14 and 18 have a tendency to shear the metal of the workpiece 12 rather than to pressure form the metal into the configuration desired.

Turning now to the present invention, FIG. 4 illustrates a cylindrical workpiece 30 to be formed with involute teeth 31. The workpiece 30 is mounted on a stationary pivot 32 located between a pair of opposed, identical rack forming tools 34. Each of the tools 34 comprises a body 36 having a leading end 38 and a trailing end 40. The body 36 has a front portion 42 extending rearwardly from the leading end 38 and a rear portion 44 extending from the front portion 42 to the trailing end 40.

A plurality of identical involute teeth 46 are formed on the rear portion, each of the teeth 46 on the rear portion 44 having a configuration that is fully conjugate to the configuration of the teeth 31 to be formed on the workpiece 30. A plurality of involute teeth 48 are formed on the front portion 42, the tips 52 of the teeth 48 on the front portion 42 being spaced from the plane (indicated by line 50 in FIG. 5) of the tips 54 of the teeth 46 of the rear portion at progressively increasing distances toward the leading end 38. That is to say, the tip 52 of the tooth 48*b* in FIG. 5 is located a distance from the plane 50 of the tip 54 of teeth 46 a distance greater than the tip 52 of tooth 48*a*. Tooth 48*c* has its tip 52 located a greater distance from plane 50 than the tip 52 of tooth 48*b*, and so forth.

Each of the teeth 48 of the front portion 42 is congruent with the teeth 46 on the rear portion from the tips 54 of the teeth of the rear portion toward the root thereof. That is to say, if a tooth 48 is superimposed on a tooth 46 with the tip 52 overlying tip 54, the surfaces of the teeth will coincide. The width of the tips 52 and 54 are the same and corresponding portions of the leading flanks 56 and 58 of teeth 48 and 46, respectively, and of the trailing flanks 60 and 62 of teeth 48 and 46, respectively, have the same relative position with respect to their respective tips so that the teeth 48 and 46 have the same cross-section from the tips 52, 54 toward the root lines 64 and 66 of the teeth 48 and 46, respectively. In the FIG. 5 embodiment, the teeth 48 of the front portion are each inclined with respect to the teeth 46 of the rear portion 44, and project the same height above the root line 64 as the teeth 46 project above the root line 66. Hence, the configuration of each tooth 48 is identical with the configuration of each tooth 46, and teeth 48 and 46 are each fully conjugate to the configuration of the teeth 31 to be formed on the workpiece 30.

As shown in FIG. 5, each tooth 48 of the front portion 42 is inclined with respect to the teeth 46 of the rear portion 44, the root line 64 of the teeth 48 being inclined toward the leading end 38 with respect to the root line 66 of the teeth 46 at an angle *y* as shown in FIG. 5. Each tooth 48 of the front portion 42 projects from the root line 64 a height equal to the height of the teeth 46 above the root line 66. Since the tips of the teeth 52 are parallel with the root line 64, and the tips 54 are parallel with the root line 66, the plane of the tips 52 is also inclined with respect to the plane 50 of the tips 54 an angle *y*.

With reference to FIG. 4, the distance between the teeth of the opposed tools 34 increases as the tools simultaneously advance in the direction of the arrows *e*. The teeth adjacent the leading ends 38 of the respective tools 34 initially engage the workpiece 30, and the teeth progressively penetrate deeper into the material of the workpiece as the tools advance in the direction of the arrows *e*. As shown in FIG. 7, as the teeth penetrate into the material of the workpiece, formation of the teeth 31 on the workpiece 30 is begun initially by the displacement of the material of the workpiece by the teeth 48. When the tool 34 is advanced to the position such that the teeth 46 of the rear portion 44 engage the workpiece, the teeth 46 penetrate the workpiece to substantially their full depth to form the conjugate teeth 31 to the full depth.

The teeth 46 adjacent the trailing edge 40 may be relieved as illustrated by reference numeral 70 in FIG. 4 by grinding the teeth down at an angle toward the rear to assist in disengaging the teeth 46 from the workpiece when the operation is completed.

In order to cause the material of the workpiece to progressively flow in a desired axial direction with respect to the workpiece, the teeth may be crowned as illustrated in FIG. 6 by forming a tapered portion on the tip of the tooth toward one edge 52*a*. The tip is tapered from a flat portion adjacent edge 52*b* toward the edge 52*a* such that the edge 52*a* has a slightly reduced height with respect to the edge 52*b*. As shown in FIG. 6, the crowning is provided by grinding the tips 52 at a radius R from approximately the midpoint of the tooth toward the edge 52*a*. The radius R is extremely large and may be on the order of 60 inches.

The juncture of the leading and trailing flanks 56 and 60 with the tip 52 has the same predetermined radius *r*. Similarly, the juncture of the leading and trailing edges 58 and 62, respectively, of teeth 46 with the tip 54 has the same predetermined radius *r*. The juncture of the leading and trailing flanks 56 and 50 with the root line 64 has the same predetermined radius *q*. Similarly, the juncture of the leading and trailing flanks 58 and 62, respectively, of the teeth 46 with the root line 66 has the same predetermined radius *q*. The full radii *r* of the teeth 46 and 48 reduce the likelihood of the metal of the workpiece being sheared by engagement with one of the teeth.

In a specific design according to the embodiment of FIGS. 5, 6 and 7, the tool 34 has a length L of 24.0000 inches and the front portion 42 has a length *b* of 18.4854 inches and includes 140.78 teeth 48. The rear portion 44 has a length a of 5.5146 inches with 42 teeth 46. The teeth adjacent the trailing end 40 are relieved over a length of 1.5756 inches. The tip of the tooth 48 at the leading end 38 is spaced below the plane of the

tips **54** of the teeth **46** a distance *c* of 0.0245 inches. The angle *y* between the root line **66** and **64** is thus the angle whose tangent is *c*/*b* or 0.0245/18.4854 which is an angle that is less than 0° 5 minutes.

FIG. **9** shows another embodiment of a tooth forming rack tool **134** having a body **136** with a front portion **142** extending rearwardly from the leading end (not shown) of the body **136**, and a rear portion **144** extending from the front portion **142** to the trailing end (not shown) of the body **136**. A plurality of identical teeth **146** are provided on the rear portion, and each of the teeth **146** on the rear portion have a configuration fully conjugate to the configuration of the teeth to be formed on the workpiece. A plurality of teeth **148** are formed on the front portion, the tips **152** of the teeth **148** on the front portion **142** being spaced from the plane **150** of the tips **154** of the teeth **146** of the rear portion at progressively increasing distances toward the leading end of the body.

Each tooth **148** on the front portion **142** is congruent with the teeth **148** on the rear portion from the tips **154** of the rear portion toward the root thereof a distance corresponding to the height of the respective front tooth **148**. Thus, if a tooth **148** is superimposed on a tooth **146** such that the tip **152** of the tooth overlies the tip **154** of the tooth **146**, all surfaces of the tooth **148** will coincide with the corresponding surfaces of the tooth **148** except that the tooth **148** will not extend from the tip as far as the tooth **146**.

In the embodiment of FIG. **9**, the body **136** has a root line **165** which is common to the front and rear portions **142** and **144**. The teeth **148** of the front portion project from the root line **165** at heights progressively decreasing toward the leading end of the body. Thus, the height of tooth **148***a* is greater than the height of tooth **148***b*, tooth **148***b* has a height that is greater than the height of tooth **148***c*, and so forth.

The configuration of each of the teeth **148** is congruent to the configuration of the teeth **146** from the tip toward the root a distance corresponding to the height of the tooth **148**. Thus, tooth **148***e* having a base line B indicated along the root line **165**, may be superimposed on the tooth **146** such that its tip **152** will coincide with the tip **154**, and its leading flank **156** will coincide with the leading flank **158** of the tooth **146**, and its trailing flank **160** coinciding with the trailing flank **162** of the tooth **146** for a distance equal to the height of the tooth **148***e*. The base line B of tooth **148***e* will be located above the root line **165** a distance *w* equal to the distance of tip **152** of tooth **148***e* below the plane **150** of the tips **154**. Thus, the teeth **148** are reduced in height in a manner that may be referred to as inversely truncated, in the sense that the base portion of the teeth are removed to reduce the height thereof so that the configuration of the teeth are congruent with the corresponding upper portions of the teeth **146**. Consequently, the width of the tips **152** as viewed in FIG. **9** is the same as the width of the tips **154** so that as a tooth engages the workpiece, the pressure is distributed over the portions of the surfaces of the leading and trailing flanks in engagement with the workpiece, and is not concentrated at the tips.

As in the previously described embodiment, the juncture of the leading and trailing flanks of each of the teeth with the respective tip thereof has the same predetermined radius. Similarly, the juncture of the leading and trailing flanks of each of the teeth with the root line **165** has the same predetermined radius.

The teeth **146** and **148** may also be crowned as indicated in FIG. **6** with regard to the previously described embodiment for the purpose of causing the metal to be displaced toward a desired end of the workpiece in an axial direction.

While specific embodiments of the invention have been disclosed in the accompanying drawings and described in the foregoing specification, it should be understood that the invention is not limited to the exact construction shown. Alterations in the construction and arrangement of parts, all falling within the scope and spirit of the invention, will be apparent to those skilled in the art.

I claim:

1. A tool for pressure forming teeth on the periphery of a cylindrical workpiece comprising: a body having a leading end and a trailing end; said body having a front portion extending rearwardly from said leading end and a rear portion extending from said front portion to said trailing end; a plurality of identical teeth on said rear portion, each of said teeth on said rear portion having a configuration fully conjugate to the configuration of the teeth to be formed on the workpiece; and a plurality of teeth on said front portion; the tips of the teeth on said front portion being spaced from the plane of the tips of the teeth of said rear portion at progressively increasing distances toward said leading end; each tooth on said front portion being congruent with the teeth on said rear portion from the tips of the teeth of rear portion toward the root thereof a distance corresponding to the height of the respective front tooth.

2. A tool as claimed in claim **1** wherein each tooth of said front portion is inclined with respect to the teeth of the rear portion.

3. A tool as claimed in claim **2** wherein each tooth of said front portion is of the same height as the teeth of the rear portion, and hence is of a configuration fully conjugate to the configuration of the teeth to be formed on the workpiece.

4. A tool as claimed in claim **1** wherein the root line of the teeth of the front portion is inclined toward the leading end with respect to the root line of the teeth of the rear portion.

5. A tool as claimed in claim **4** wherein each tooth of the front portion projects from the root line of the front portion a height equal to the height of the teeth of the rear portion above the root line of the rear portion.

6. A tool as claimed in claim **1** wherein said body has a root line common to said front and rear portions.

7. A tool as claimed in claim **6** wherein the teeth of the front portion project from said root line at heights progressively decreasing toward the leading end of said body.

8. A tool as claimed in claim **1** wherein the tip of each of said teeth is crowned toward one edge thereof such that said one edge has a reduced height with respect to the other edge of the tip.

9. A tool as claimed in claim **1** wherein the juncture of the leading and trailing flanks of each of said teeth with the tip thereof has the same predetermined radius.

10. A tool as claimed in claim **9** wherein the juncture of the leading and trailing flanks of each of said teeth with the associated root line has the same predetermined radius.

11. A tool for pressure forming teeth on the periphery of a cylindrical workpiece comprising: a body having a leading end and a trailing end; said body having a front portion extending rearwardly from said leading end, and a rear portion extending from said front portion to said trailing end; a plurality of identical teeth on said rear portion, each having a configuration fully conjugate to the configuration of the teeth to be formed on the workpiece, said teeth on said rear portion each projecting from the same root line; and a plurality of teeth on said front portion each of which is identical to the teeth on said rear portion and hence has a configuration fully conjugate to the teeth to be formed on the workpiece, said teeth on said front portion each projecting from the same root line on said front portion, said last named root line extending at an angle from the root line of the teeth of said rear portion such that the tips of the teeth on said front portion are spaced from the plane of the tips of the teeth on said rear portion at progressively increasing distances toward said leading end.

12. A tool for pressure forming teeth on the periphery of a cylindrical workpiece comprising: a body having a leading end and a trailing end; said body having a front portion extending rearwardly from said trailing end and a rear portion extending from said front portion to said trailing end; a plurality of identical teeth on said rear portion, each having a configuration fully conjugate to the teeth to be formed on the workpiece; and a plurality of teeth on said front portion; said teeth on said front portion and said teeth on said rear portion projecting from a common root line; said teeth on said front por-

tion projecting from said root line at heights progressively decreasing toward the leading end of said body; said teeth on said front portion being congruent with the teeth on the rear portion from the tips toward the root line a distance corresponding to the height of the respective front tooth.

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