United States Patent

Loos

[15] **3,704,612**

[45] **Dec. 5, 1972**

[54] **TOOTHED TOOL AND DEVICE FOR CHIPLESS GENERATION OF GEARS**

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[73] Assignee: **Carl Hurth Maschinen -und Zahnradfabrik**

[22] Filed: **June 8, 1970**

[21] Appl. No.: **44,473**

Related U.S. Application Data

[63] Continuation-in-part of Ser. Nos. 813,416, April 4, 1969, abandoned, and Ser. No. 876,779, Nov. 14, 1969, abandoned.

[30] **Foreign Application Priority Data**

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Nov. 28, 1968	Germany	G 68 09 101.0
Jan. 28, 1970	Germany	G 70 02 784.8

[52] **U.S. Cl.** **72/102,** 29/159.2

[51] **Int. Cl.** **B21h 5/00**

[58] **Field of Search** 72/102, 107, 108, 365, 366; 29/159.2

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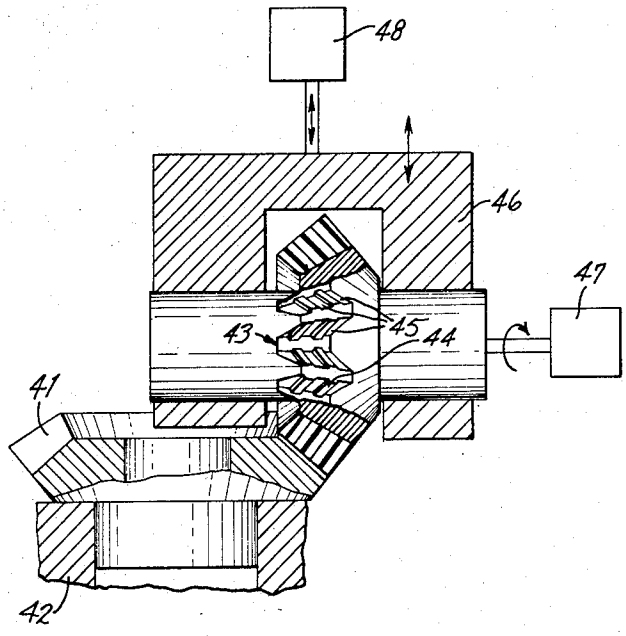
Primary Examiner—Lowell A. Larson

Attorney—Woodhams, Blanchard & Flynn

[57] **ABSTRACT**

Apparatus and tool therefor for forming teeth on the peripheries of gear blanks by rolling. A plurality of teeth are provided on the tool, each thereof having a plurality of spaced projecting areas for applying localized pressures onto the workpiece and arranged in laterally offset relationship for laterally progressively roll-forming each tooth on the periphery of the gear blank, simultaneously with the inwardly radial progression thereof, without the production of chips or shavings. Means are also provided for changing the spacing between the axes of the tool and the gear blank to effect by rolling the formation of teeth on the gear blank.

28 Claims, 19 Drawing Figures



PATENTED DEC 5 1972

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SHEET 1 OF 5

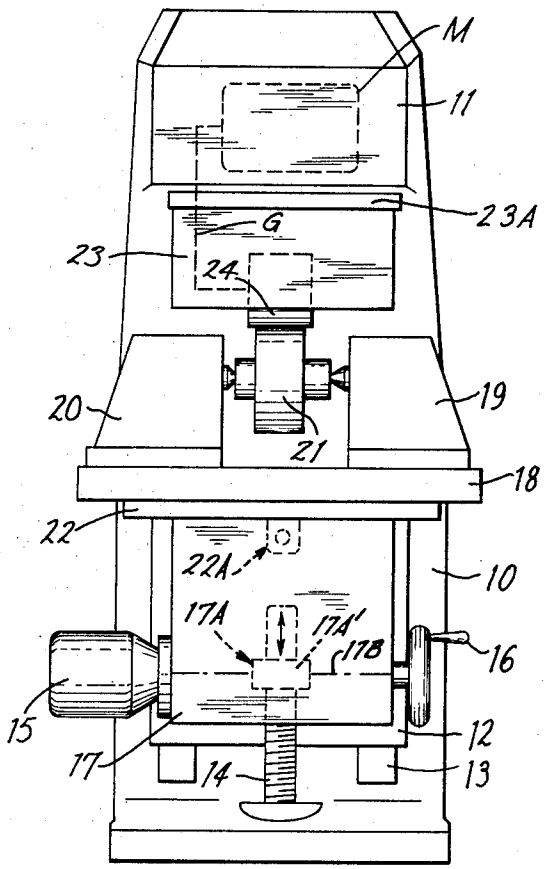


Fig. 1

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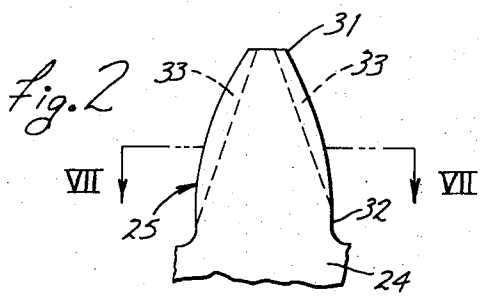


Fig. 2

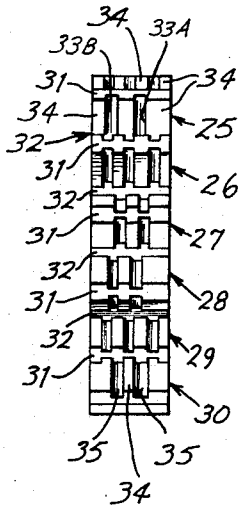


Fig. 3

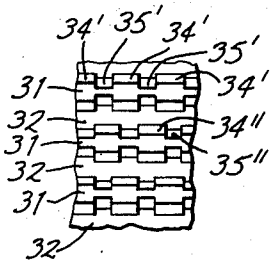


Fig. 4

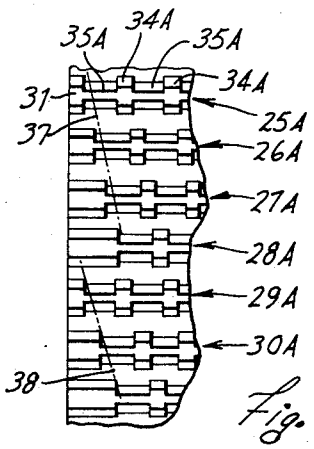


Fig. 5

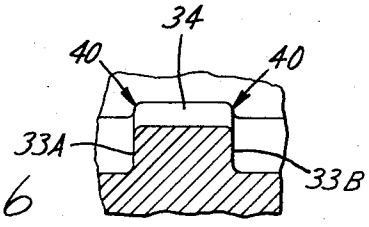


Fig. 6

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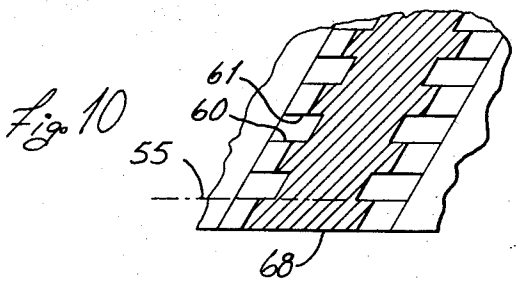


Fig. 10

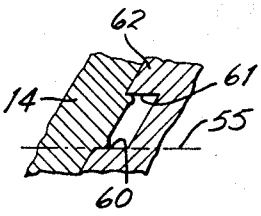


Fig. 11

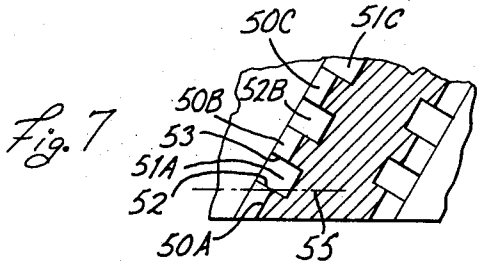


Fig. 7

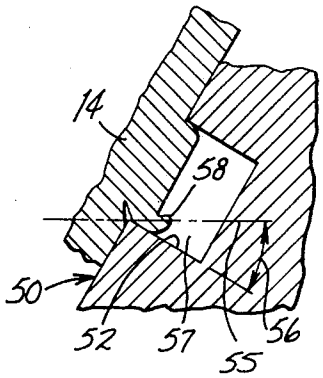


Fig. 8

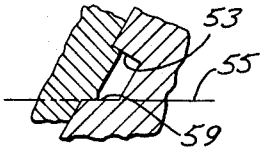


Fig. 9

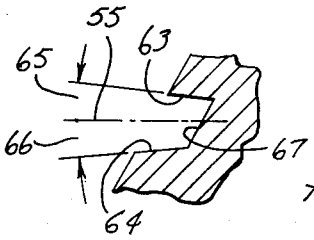


Fig. 12

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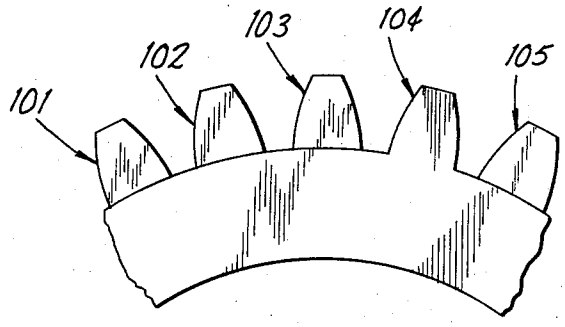


Fig. 13

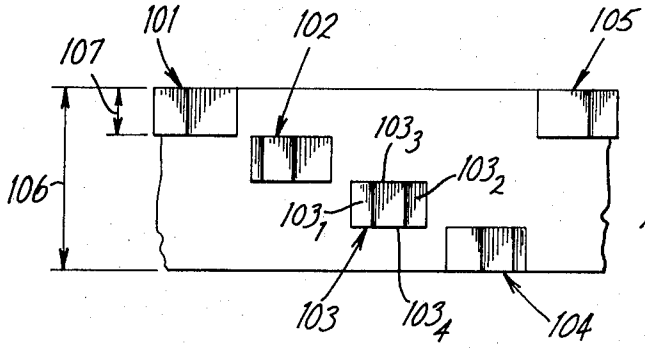


Fig. 14

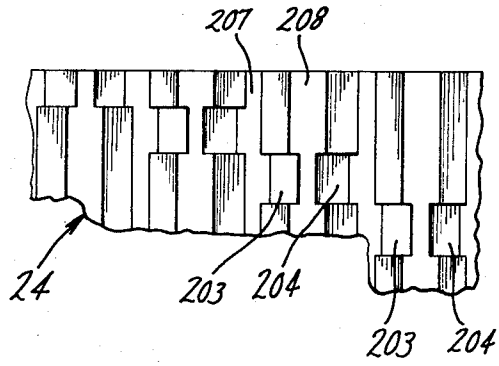


Fig. 15

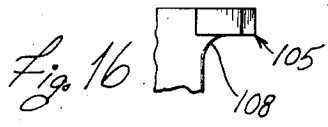


Fig. 16

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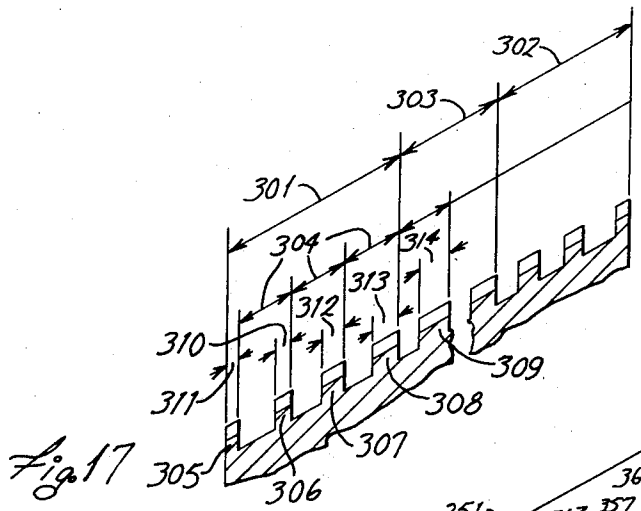


Fig. 17

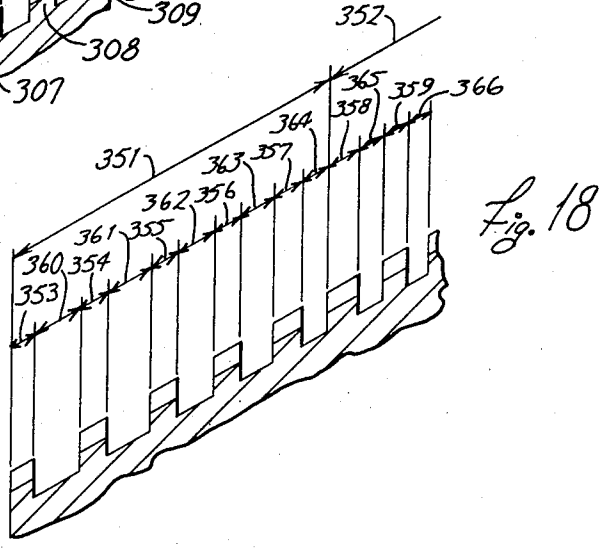


Fig. 18

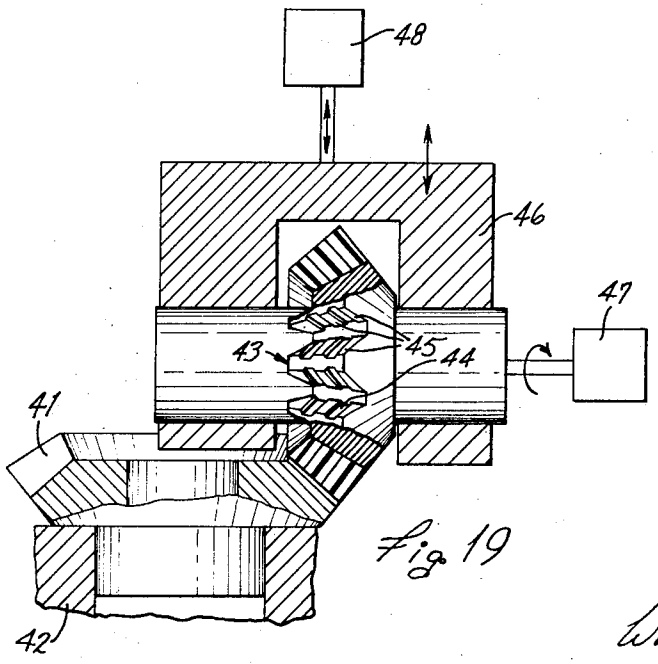


Fig. 19

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TOOTHED TOOL AND DEVICE FOR CHIPLESS GENERATION OF GEARS

This application is a continuation in part of application Ser. No. 813,416 filed Apr. 4, 1969 now abandoned and Ser. No. 876,779 filed Nov. 14, 1969 now abandoned.

FIELD OF THE INVENTION

This invention relates to an apparatus for the chipless generation of spur, helical and bevel gears and to tools therefor.

BACKGROUND OF THE INVENTION

In known apparatus for a chipless generation of gears, the tool teeth roll in the full face width on the teeth being formed on the workpiece, whereby a pressure acts radially both on the workpiece and on the tool. A certain surface pressure is required for forming the tooth surfaces of the workpiece. To produce such surface pressure a corresponding predeterminable and relatively large contact force is required. To handle said contact force and for receiving the loads thereby imposed it is necessary to provide very strong carriers for both the workpiece and the tool and to provide equally strong bearings. Further, it is necessary to provide a correspondingly great drive source for the rolling operation.

It is the purpose of the invention to reduce the required contact force while maintaining an undiminished unit surface pressure.

A further purpose of the invention is to make it possible to simplify the machine for a chipless forming of gears. While in the known machines two and more tools are positioned opposite each other with respect to the workpiece in order to accept the high forces required for forming, the invention makes it possible to use only one single tool.

It is a further purpose of the invention to chiplessly work or generate spur, helical and bevel gears having a face width of more than ½ inch or a diametral pitch equal to or greater than 13 with one single tool.

A further purpose of the invention is to make possible a construction of the machine for a chipless generation considerably lighter and less expensive than the known machines while at the same time providing the requisite rigidity in the support for a workpiece having a face width of more than ½ inch and which are larger than DP13 and to accomplish this by an operation requiring only a single tool.

It is a further purpose of the invention to make possible the very accurate, chipless production of a variety of desired products, such as gears by a tool which applies at any given moment only a localized pressure to a workpiece area less than the full tooth width and accomplishes such by the presence on the tool of projecting (effective) and recessed (ineffective) areas.

The apparatus can, if desired, be arranged in such a manner that the workpiece and tool roll under a radial contact force with the axes of the workpiece and the tool being crossed at a spacing corresponding to the difference between the prior working dimension and the finished dimension of the workpiece and where the edges formed at the tooth surfaces between the ineffective surfaces and the effective surfaces may be dull. In this manner, a relative sliding motion is obtained

between the tool tooth surface and the workpiece tooth surface in a direction lengthwise of the tooth. Since according to the invention no shaving is removed, at least no shaving which justifies the term "chip removing working," an additional squeezing, which can be advantageous, is performed through this longitudinal sliding.

A further purpose of the iinvention is to provide an apparatus in which a relative movement of the one tooth surface along the other tooth surface is provided but in spite of this no appreciable quantity of chips is removed.

A still further purpose of the invention is the production of tools for a chipless generation of gears by rolling with which a great surface pressure can be exerted at a relatively small total contact force.

A further purpose of the invention is to provide a tool for a chipless generation of gears with which all flank portions of the gear teeth are rolled uniformly. The contact force can be reduced further if the ribs are constructed narrower than the width of the ineffective surfaces and the tool is constructed so that the effective surfaces are arranged helically on the successive teeth. Depending on the desired relation of contact force and surface pressure, the effective surfaces extend on the successive teeth along one or multiple helices. Thus, the required contact of the effective surfaces and the desired and optimum number of overrollings must be considered. The invention is accordingly further developed in that in one embodiment a new helix starts at least at each third tooth. The number of teeth from the start of one helix to the start of the next helix is often called a group. The number of teeth from the start of one helix to the start of the next helix is then the group teeth count.

A further purpose of the invention is to provide that errors in tooth shaping, for example profile errors, are not greater at the sides of the workpiece than at the center thereof.

The invention, in particular the tools according to the invention are not only advantageous for finish rolling but also for forming in solid.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front elevational view of a machine for roll-forming teeth on the periphery of a gear blank;

FIG. 2 is a side elevational view of a tooth on a tool embodying the invention;

FIG. 3 is a top plan view of a tool embodying the invention;

FIG. 4 is a top plan view of a modified gear like or rack like tool;

FIG. 5 is a top plan view of still another modified gear like or rack like tool;

FIG. 6 illustrates schematically in an enlarged scale a cross section of an effective surface portion a tool embodying the invention, said effective surface being defined by two ineffective surfaces;

FIG. 7 is a sectional view taken along the line VII—VII of FIG. 2;

FIG. 8 illustrates a detail of FIG. 7 and further illustrates schematically the damaging effect of an ineffective surface if improperly constructed;

FIG. 9 illustrates a preferred detail of an ineffective surface;

FIG. 10 is a cross sectional view taken approximately along the line VII—VII of FIG. 2 and illustrates one form of the invention;

FIG. 11 illustrates in an enlarged scale a detail of FIG. 10;

FIG. 12 illustrates an ineffective surface according to a further construction of the invention;

FIG. 13 is a side elevational view of a modified tool embodying the invention;

FIG. 14 is a top plan view of the tool illustrated in FIG. 13;

FIG. 15 is a top plan view of a modified tool embodying the invention;

FIG. 16 is a fragmentary top plan view of a single tooth of the embodiment illustrated in FIG. 14;

FIG. 17 is a fragmentary sectional view taken approximately along the line VII—VII of FIG. 2 and illustrates a modified form of the tool;

FIG. 18 is a modified form of the tool illustrated in FIG. 17; and

FIG. 19 is a fragmentary front elevational view of a rolling machine and a tool for roll-forming teeth on a bevel gear blank.

SUMMARY OF THE INVENTION

Briefly, the invention comprises providing a gear rolling tool with a plurality of alternate projecting (effective) and recessed (ineffective) surfaces, same being arranged in such a pattern that as such tool is operated against a blank the several effective surfaces will act on enough localized areas of the workpiece as eventually to apply the required pressure onto the entire tooth flank and effect the desired tooth, and thereby gear, shaping without the formation of chips.

DETAILED DESCRIPTION

FIG. 1 illustrates an example of a machine for the precision noncutting forming of spur and helical gears according to the invention. The machine frame **10** is constructed in a known manner in a C-shape. A cantilevered portion **11** projects from an upstanding back portion to form the upper leg of the "C" and a similarly projecting workpiece carriage **12** forms the lower leg of the C. The workpiece carriage **12** is guided for vertical movement in vertical guides **13** which are secured on, or are integral with said machine frame. The workpiece carriage **12** can be vertically adjusted along the above-mentioned guides **13** by a feed spindle **14** and can be fed to effect a change in the distance between the axes of the later-described tool and the workpiece. The handwheel **16** is provided and usually used to preadjust the distance between the axes while an electric motor **15** can effect advancement during a rolling operation. Any conventional gearing is provided between a feed spindle **14** or a feed unit **17A'** and the electric motor **15** or the handwheel **16** may be located in a gear housing **17** and is schematically illustrated at **17A**. In this schematic illustration, the feed nut **17A'** is threaded onto the feed spindle **14** and is rotated in any conventional convenient manner by either the hand wheel **16** or the motor **15** through a shaft **17B**. However, it is also possible to provide the feed spindle and feed nut only to preadjust the distance between the axes as the initial dimension for the feeding while the actual feeding is done with a known and therefore not illustrated cam or a feed screw and a feed unit **22A**. This feeding shall be called "plunge feed." Further details of the machine and means typical for plunge feeding the workpiece are illustrated in our U. S. Pat. Nos. 3,115,064, 3,245,320, 3,246,568 and reference is made thereto.

To assure a successful operation, the following feed cycle may be effectively used: plunge feeding of the workpiece toward the tool in a direction substantially along, or at least parallel to, a line normal to the axes of both the tool and the workpiece until surface contact is attained between the tool and the workpiece; further similar plunge feeding to effect work; a dwell at the smallest distance between the axes; a slight moving off to relieve the elastic tension in machine, tool and workpiece; then quick return movement to the initial position.

The workpiece carriage **12** or the gear housing **17**, here the carriage **12**, supports a workpiece table **18** which, by means of retaining pieces **19**, **20** or other supports, receives the workpiece **21** in such a manner that it can rotate. The axis of the workpiece is by these retaining pieces held perpendicularly to the above-mentioned guides **13** and a slide **22** can be provided between the workpiece carriage **12** and the workpiece table **18** to adjust the workpiece for positioning perpendicularly below the tool **24** hereinafter mentioned. The slide **22** is drivable in a known manner through gear elements (not illustrated) and a feed spindle mechanism **22A** in a direction perpendicular to said above-mentioned line normal to the axes of the workpiece and the tool. Further details of the machine, and typical means for moving the workpiece horizontally, are also illustrated in our above mentioned U. S. Patents.

The tool **24** of the invention is rotatably supported by means of a workpiece support **23** on the upper leg or overhang **11** of the C-shaped frame. It is a particular advantage of the invention that only a single tool is required for carrying out an effective and an efficient rolling operation. The tool will be described in detail below. The tool can be driven in a known manner by a motor M through a gearing schematically illustrated in dotted lines at G in FIG. 1 and shown for instance on our U. S. Pat. No. 3,115,064. During the rolling operation, the tool **24** is in meshing engagement with the workpiece **21**; the axes of the workpiece and tool are in this embodiment positioned parallel to each other.

According to a further embodiment of the invention, the work tool support **23** can also be arranged for pivotal adjustment and securement on the machine frame in any convenient, conventional manner for instance as shown in our U. S. Pat. No. 3,115,064 so that the pivot plane **23*a*** is positioned perpendicularly to the direction of the feed movement by the feed spindle mechanism **22A**. By means of this pivoting device, the tool axis can be adjusted in such a plane relative to the workpiece axis that said axes cross at an angle selectable by rotation in such plane of the tool support **23**. The common normal to said axes is positioned parallel to the plunge feed direction and perpendicularly to the aforementioned pivot plane.

FIG. 2 illustrates a tooth **25** of a gearlike tool according to the invention on an enlarged scale. FIG. 3 illustrates the gearlike tool, namely as seen radially toward the periphery of the tool. The flanks of the teeth **25** to

30 of the tool (FIG. 3) are interrupted with offset surfaces 33 to form (*a*) effective surface portions 34 (FIG. 3) which project toward the tooth space and thus toward the workpiece tooth and are therefore effective for the purposes of the invention and (*b*) ineffective surface portions 35 which are recessed from the tooth surface and are therefore ineffective. The ineffective surface portions 35 result in a reduction of the effective face width of the tool; thus the force with which the tool is pressed onto the workpiece is concentrated onto the effective flank portions 34. A tool which has uninterrupted tooth surfaces requires a large contact force to provide a large surface pressure. Thus, where the tooth surfaces are interrupted, as in the present invention a smaller force is required to produce the needed surface or unit pressure for forming than would be required if the tooth surfaces were uninterrupted. In order to assure that all surface portions of the workpiece are worked during the rolling operation, the ineffective surface portions 35 or the effective surface portions 34 are offset, e.g., staggered, on successive teeth, such offsetting being regularly or irregularly arranged as desired provided only that the proper amount of working is applied to all portions across the full width of each tooth.

In effect then, the spaced effective surface portions above referred to provide a series of spaced pressure surfaces 34 which are arranged in two directions, namely a direction generally parallel to the direction of relative movement between the workpiece and the tool and in a direction laterally thereto, said lateral direction being usually approximately perpendicular, or at some other wide angle, with respect to the first direction. By the offset or staggering of successive surfaces as above mentioned, the spacing in the above mentioned two directions in some preferred embodiments results in arrangement of said pressure areas in one or more helices around the periphery of the tool as set forth in more detail below.

FIG. 4 illustrates an embodiment which is very important for the invention in that the ineffective surface portions 35′ and the effective surface portions 34′ of one tooth are positioned so as to face the effective surface portions 34″ and the ineffective surface portions 35″ of an adjacent tooth. FIG. 4 schematically illustrates an unwound portion of such a tool, which portion comprises three teeth. The effective surface portions 34′ and 34″ must at a minimum be made as wide as the ineffective surface portions 35′ and 35″. If the above described tool is compared to a tool without interruptions, the applied pressure necessary to produce the same contact pressure as in the case of a tool without interruptions can be reduced by one-half or slightly more than one-half. When the contact pressure is slightly more than one-half, the amount over the one-half equals the magnitude by which the width of the effective surface portions exceed the width of the ineffective surface portions.

FIG. 5 schematically illustrates another embodiment of the invention unwound and viewed from above the tooth tops 31. The effective surface portions 34a are here considerably narrower than the ineffective surface portions 35*a*. In order to work all parts of the tooth surfaces on the workpiece, the effective surface portions 34*a* are arranged on helix lines 37, 38 on the successive teeth 25*a* to 30*a*, etc. In the illustrated embodiment, a new helix line starts every four teeth. In this case, the applied pressure may be one-fourth of that which would be required if the tooth surfaces were not interrupted by ineffective surface portions. The number of teeth from the start of one helix to the start of the next one, in this example four teeth, is also called "group teeth count." The group teeth count will vary according to the individual job to be done.

In all the embodiments described above, the edges 40 (FIG. 6) which are formed by the effective surface portions 34 and the receding surfaces 33a, 33b are not intended to remove shavings, in any case not to a degree that the term "cutting working" would be justified due to the fact that the edges 40 are deliberately made dull. In the case of the provision of a lengthwise feed (using the slide 22), the edges 40 should be sufficiently dull that they do not remove any shavings, or at least any shavings worth mentioning.

FIG. 7 is a cross-sectional view taken along the line VII—VII of FIG. 2. A series of effective surface portions 50A, 50B, 50C and ineffective surface portions 51A, 51B, 51C are provided in each tooth surface. The receding surfaces 52, 53 form a right angle with the surfaces of the effective surface portions 50A, 50B, 50C. One of the receding surfaces, here 52 (FIG. 8) forms with the plane of rotation 55, which plane 55 is perpendicular to the axis of the tool, an angle 56. This angle is called the undercut angle 56 (FIG. 8). A pocket 57 which is not filled with tool material is formed by the undercut angle. When the tool rolls on the workpiece 14, workpiece material 58 is torn out, results in an unclean workpiece surface, and gathers in the pocket 57.

FIG. 9 illustrates a receding surface 59 in which the above referred to disadvantage is avoided. The receding surface which, without the invention, would form the above described pocket 57 is placed according to the invention in or parallel to the plane of rotation 55. Thus, formation of a pocket is avoided, no material can be torn out and the workpiece surface is of a higher quality. In this embodiment, the walls 53 and 59 converge because the wall 53 has maintained its above-described position, namely perpendicular to the effective tooth surfaces and the ineffective tool surfaces.

FIGS. 10 and 11 illustrate a further advantageous exemplary embodiment of the invention in which both receding surfaces 60, 61 adjacent to one tooth surface are both parallel to the plane of rotation 55. The thus formed effective surface portions 62 (FIG. 11) might penetrate more easily into the workpiece material than for example the edge formed by the receding surface 53 (FIG. 9). This will improve the solidity and sturdiness of the rolling apparatus.

FIG. 12 illustrates an embodiment of the invention in which both receding surfaces 63, 64 adjacent one tooth surface converge to form equal angles 65, 66 with the plane of rotation 55 placed through the center of the respective flank portion. The receding surfaces thus converge toward the ineffective surface portions 67. From the standpoint of manufacture of the tool for making the receding surfaces, it is also advantageous to construct the tool with both receding surfaces forming equal angles with the plane of rotation 55 but with the plane being directed perpendicularly to the tooth surface.

The invention can also be used for racklike tools. The illustration of FIG. 2 would, in such a case, change only in that the tooth surfaces would be straight instead of curved. FIGS. 9 to 12 would remain unchanged. The plane of rotation for a tool used to make a gear thus becomes the rolling plane for a tool used to make a rack (which is also the plane of rotation of the tool). The rolling plane is normally positioned parallel to the surface 68 (FIG. 10) of the rack-shaped tool.

FIGS. 13 and 14 illustrate still a further embodiment of the invention. The teeth 101 to 105 of the tool 24 do not extend the total width 106 of the tool but, instead, are defined by walls 103/3, 103/4 so that they are narrower (for example the width 107) and can act only onto one portion of the workpiece surfaces at a time. In order to successively work all portions of the workpiece surfaces, the teeth 101, 102, 103, 104, 105 are arranged staggered in a circumferential direction. In the example of FIG. 14, one face width on the workpiece is worked after an engagement of four tool teeth, of course, the worked surface portions lie first still on different workpiece teeth. In order that all surface portions of the workpiece are worked, the workpiece teeth count and the tool teeth count must be selected with respect to one another. For example, the teeth counts may not be the same or must always leave a remainder. In this embodiment, the tooth surfaces, for example 103/1, 103/2, with respect to the tool tooth 103 are opposite one another so that the forces acting onto the tool tooth are balanced. FIGS. 13 and 14 present only schematic illustrations drawn more for clarity in setting forth the invention than for precise accuracy in picturing the teeth.

FIG. 15 illustrates still a different embodiment of a tool according to the invention. A portion of a tool 24 is schematically illustrated, namely same is unwound and seen from above the tooth tops 207 and the bottom land 208. The effective surface portions 203, 204 are arranged on opposing sides of a pair of teeth in such a manner that they occupy or lie in the same rolling plane for each tooth space. In this manner the forces acting onto the workpiece tooth are also balanced.

FIG. 16 illustrates one embodiment in which each of the teeth, here tooth 105, are provided between the offset surface and hub body with a fillet having a large radius 108.

A chipless generation of gears, in particular of helical gears, in the zone near the sides of the gears, tooth errors, in particular profile errors, can exist even though in the zone of the tooth center little or no errors exist. To assure that the entire workpiece face width is worked to produce the same quality throughout, the tools can be constructed as is schematically illustrated in the FIGS. 17 and 18. FIG. 17 illustrates in a cross section, sectioned approximately along the line VII—VII of FIG. 2, of one side of a tooth of a tool on an enlarged scale. The tooth is broken out in the center so that the sketch does not show the entire face width which is meaningless for this portion of the invention but only the ends thereof. The entire face width is divided into two zones 301, 302 at the ends of the tooth and one zone 303 at the center of the tooth. The spacing 304 of corresponding blanks of the effective surface portions 305, 306, 307, 308, 309, etc. are equal over the entire face width. However, the widths of the effective surface portions progressively increase from the ends toward the center. For example, the width 311 of the effective surface portion 305 at the side of the gear tooth is the narrowest. From here the widths 310, 312, 313, 314, etc. successively increase until, at the beginning of the zone of the tooth center, the greatest face width is reached. In the zone 303 of the tooth center, the width 314 preferably remains the same and then again decreases toward the other side of the gear (zone 302). The invention can also be carried out so that, for example in the zones at the sides of the teeth, the ineffective flank portions are of equal width but relatively narrow and in the zone at the center of the tooth same are also of equal width but relatively wide. Various other combinations are possible, provided only that the surface pressure is greater at the sides of the gear teeth than in the center thereof. By staggering the ineffective surface portions on the successive teeth, as has been illustrated and described earlier, it will be assured that at all widths of the teeth the blanks thereof will be rolled uniformly.

FIG. 18 illustrates a different embodiment which also serves to produce a greater surface pressure at the sides of the teeth than at the tooth center. Again in an enlarged scale and on a cross section taken approximately along the line VII—VII of FIG. 2 there is illustrated a portion of one side of a tooth, namely a zone 351 at the side of a tooth and a zone 352 at the tooth center, only a portion of the tooth center zone being illustrated. The widths 353 to 359 of the effective surface portions are the same over the entire face width, however, the ineffective surface portions 360 to 364 become smaller toward the center zone. In the center zone, the ineffective surface portions 365, 366 remain the same and again increase toward the other side. In this embodiment, also care must be taken to effect a suitable staggering.

Combinations of the systems according to FIGS. 17 and 18 can also be used to attain the objectives of the invention.

FIG. 19 illustrates schematically an apparatus for applying the invention for the precision noncutting forming of bevel gears. The workpiece 41 is clamped in a workpiece receiver 42 which is rotatably supported in any suitable manner. The bevelled tool 43, the tooth flanks of which are, according to the invention, provided with recessed, ineffective portions 44 and projecting effective surface portions 45, is replaceably received by a tool support 46. Workpiece and tool are in meshing engagement during the working. For the forming movement, the tool is driven by a motor 47 through any conventional elements (not illustrated). The working speed can be preselected or regulated as desired. Also, the direction of the rolling movement can be selected and/or changed as desired. The tool support 46 can be driven for a vertical feed movement by another motor 48 through conventional gear elements (not illustrated). The direction of the ineffective surfaces 44 depends on the direction of the rolling movement. As before, the edges of the receding surfaces are not intended to remove shavings. At least, any such removal, if there is any, is in small and substantially ineffective quantities.

OPERATION

Although the operation of the roll-forming apparatus described above will be understood from the foregoing description by those skilled in the art, a summary of such description is now given for convenience.

After the gear blank or workpiece **21** is placed in the retaining pieces **19** and **20** to support same for rotation and the hand wheel **16** or the motor **15** rotated to move the gear housing **17** vertically along the guides **13** to adjust to a desired value the spacing between the axis of the tool **24** and the axis of the gear blank **21**, the motor M may be energized to rotatably drive the tool **24**. Simultaneously therewith, the motor **15** may be energized to drive the feed spindle **14** or the feed screw mechanism **22A** to move the workpiece **21** to bring the surface to be worked into engagement with the tool. In the case of the tool and workpiece having axes skewed but in parallel planes, such movement in one effective embodiment is first perpendicular to the common normal between said axes to align the workpiece and tool and then parallel to said common normal to bring the workpiece into contact with the tool. However, other feeding motion combinations are possible and will be recognized by those skilled in the art. In the case of the tool and workpiece having parallel axes, the common normal in the sense above used is the one through the center of the tool.

The process of rolling teeth on the gear blank is best achieved by first bringing the surface to be worked on workpiece **21** into initial engagement with the tool **24**. The surface to be worked on the workpiece **21** is then forcibly driven into meshing engagement with the tool **24** to effect by rolling a laterally, regularly or irregularly, progressive forming of teeth by deforming the material of the workpiece **21**. That is, the laterally offset effective surface portions and ineffective surface portions on a particular tooth of the tool will, upon engaging the surface to be worked on the workpiece, form at any one time only a portion of the lateral face width of the newly formed tooth on the workpiece. As the tool **24** is rotated, the successive teeth of the tool will engage the remaining surface to be worked to laterally complete the form thereof into a finished product.

After the minimum spacing between the axes of the workpiece and the tool is achieved, the minimum spacing can be maintained for a short period of time while both the tool and workpiece are rotating after which time the axes can be separated slightly to relieve the stress on the components of the machine but without completely disengaging the tool from the workpiece. The workpiece and the tool are separated quickly to the initial position.

The above described operation also applies to the embodiment of the apparatus illustrated in FIG. **19**. In this embodiment, the workpiece is held stationary and the tool **43** is driven downwardly into engagement with the surface to be worked on the workpiece **41**. It is recognized that the workpiece could as well be driven, if desired, into engagement with the tool **43** to accomplish the same result without any appreciable change in the structural components of the machine.

Further, it is recognized that, where desired, both the workpiece and the tool may be synchronously driven for rotation during the rolling operation rather than relying on the driving power of the tool to rotate the workpiece meshingly engaged therewith.

Although particular preferred embodiments of the invention have been disclosed in detail for illustrative purposes, it will be recognized that variations or modifications of the disclosed apparatus, including the rearrangement of parts, lie within the scope of the present invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Apparatus for forming an irregular contour onto the surface of a workpiece by imposing pressure thereon, comprising:

work holding means;

a single toothed tool having means providing a plurality of separate peripheral pressure applying surfaces, said surfaces being spaced from each other on the teeth of the tool in a first direction and in a second direction, said directions being angular to each other;

means for moving said tool and workpiece support toward and away from each other;

further means for rolling said tool along relative to said workpiece, whereby said spaced pressure applying surfaces will apply pressure to said workpiece sufficiently to cause flow of the material thereof and said pressure applying surfaces will apply such pressure successively to localized zones following along both the direction of the rolling motion and laterally thereto.

2. Apparatus according to claim **1**, wherein said spaced zones are arranged both circumferentially and axially spaced with respect to each other.

3. Apparatus according to claim **2**, wherein said spaced pressure surfaces are arranged with respect to each other to define at least one helix on a periphery of said tool.

4. Apparatus according to claim **2**, wherein said spaced pressure surfaces are arranged to define a plurality of helices around the circumference of said tool.

5. Apparatus according to claim **1**, wherein both said tool and said workpiece are circular for the purpose of forming a gear from said workpiece.

6. Apparatus for forming teeth on the peripheries of gear blanks by rolling, comprising:

first rotary means for mounting a gear blank for rotation about an axis of rotation;

second rotary means comprising a tool mounted for rotation, said second rotary means having a plurality of teeth around the periphery thereof;

drive means for at least one of the first and second rotary means;

means for radially and laterally roll-forming each tooth on the periphery of said first rotary means without the production of chips or shavings, said means including means defining interruptions on the tooth surfaces dividing said tooth surfaces into successive and alternate effective surface portions and ineffective surface portions, said effective surface portions on successive teeth being axially offset from each other with receding surfaces interconnecting said effective surface portions and said ineffective surface portions; and

means for changing the spacing between the axes of said first and second rotary means.

7. Apparatus according to claim 6, wherein said means for changing the spacing between the axis of said first rotary means and said surface to be worked effects by rolling a circumferentially progressive forming of said teeth on said second rotary means simultaneous with said lateral formation of said teeth.

8. Apparatus for forming teeth on the peripheries of gear blanks by rolling, comprising:

first rotary means for mounting a gear blank for rotation about a first axis of rotation;

second rotary means comprising a tool mounted for rotation about a second axis parallel to said first axis, said second rotary means having a plurality of teeth around the periphery thereof, the tooth surfaces of said plurality of teeth having means defining interruptions therein to divide said tooth surfaces into spaced and alternate effective surface portions and ineffective surface portions, said effective surface portions on successive teeth being axially offset from each other with receding surfaces interconnecting said effective surface portions and said ineffective surface portions, the edges defined by said effective surface portions and said receding surfaces lying in planes perpendicular to the axis of said second rotary means;

drive means for at least one of the first and second rotary means; and

means for changing the spacing between said axes of said first and second rotary means to effect an engagement of said first rotary means with said second rotary means to effect a formation of teeth on the periphery of said first rotary means, said receding surfaces cooperating with said first rotary means to prevent a formation of chips or shavings during said rolling.

9. Apparatus for forming teeth on the peripheries of gear blanks by rolling, comprising:

first rotary means for mounting a gear blank for rotation about a first axis of rotation;

second rotary means comprising a tool mounted for rotation about a second axis coplanar with said axis of said first rotary means, said second rotary means having a plurality of teeth around the periphery thereof, the tooth surfaces of said plurality of teeth having means defining interruptions therein to divide said tooth surfaces into spaced and alternate effective surface portions and ineffective surface portions, said effective surface portions on successive teeth being axially offset from each other with receding surfaces interconnecting said effective surface portions and said ineffective surface portions, said receding surfaces cooperating with said first rotary means to prevent a relative sliding motion between said first and second rotary means in a longitudinal direction of said tooth surfaces;

drive means for at least one of the first and second rotary means; and

means for changing the spacing between the axes of said second rotary means and the surface to be worked on said first rotary means to effect an engagement of said first rotary means with said second rotary means to effect a formation of teeth on said first rotary means, said receding surfaces further cooperating with said first rotary means to prevent a formation of chips or shavings during said rolling.

10. Apparatus according to claim 9, wherein said second rotary means comprises a single gearlike tool member.

11. A gearlike tool for use in machines for forming teeth on the peripheries of gear blanks by rolling, comprising:

a rotary member in the form of a gear having a plurality of teeth around the periphery thereof;

means on said rotary member adapted to laterally roll form each tooth on the periphery of said gear blank, said means defining interruptions on the tooth surfaces of said plurality of tool teeth to thereby divide said tooth surfaces into spaced and alternate effective surface portions and ineffective surface portions, said effective surface portions on circumferentially successive teeth being axially offset from each other, and receding surfaces interconnecting said effective surface portions and said ineffective surface portions, the edges defined by said effective surface portions and said receding surfaces lying in planes perpendicular to the axis of said rotary member.

12. A tool according to claim 11, wherein the edges of the tooth surfaces of said teeth are dull to prevent a cutting of the material of said gear blank.

13. A tool according to claim 11, wherein said effective surface portions and said ineffective surface portions on one tooth are at least partially opposed to the respective ineffective surface portions and the effective surface portions on an adjacent tooth.

14. A tool according to claim 11, wherein said effective surface portions and said ineffective surface portions on circumferentially successive teeth are arranged in a helical pattern.

15. A tool according to claim 14, wherein a new helical pattern begins after every third successive tooth.

16. A tool according to claim 11, wherein at least one of the opposed receding surfaces are positioned parallel to a plane of rotation for said tool.

17. A tool according to claim 11, wherein the opposed receding surfaces converge in direction of said ineffective surface portions to thereby prevent a collection of material of said gear blank at said receding surfaces.

18. A tool according to claim 17, wherein at least one of said receding surfaces is parallel with said plane of rotation of said tool.

19. A tool according to claim 17, wherein said opposed receding surfaces on opposite sides of a theoretical angle bisector which bisects the angle defined by said converging opposed receding surfaces and which is parallel to the plane of rotation, each define an acute angle with said angle bisector.

20. A tool according to claim 11, wherein the sum of the effective surface portions of a tooth surface is less in the zone adjacent the sides of the teeth than in the central zone of the teeth.

21. A tool according to claim 11, wherein the effective surface portions are narrower in the zone near the sides of the teeth than in the central zone of the teeth.

22. A tool according to claim 11, wherein the width of the effective surface portions is the same over the width of the tooth and the separation between the effective surface portions is larger in the zone adjacent the sides of the teeth than in the central zone of the teeth.

23. A method for roll-forming teeth on the peripheries of gear blanks by rolling, comprising the steps of:
rotating a workpiece and a toothed tool;
moving the workpiece and the toothed tool toward each other to bring the surface to be worked on the gear blank into initial engagement with the tool;
further moving the workpiece and the tool toward each other to forcibly drive the tool into meshing engagement with the surface to be worked on the workpiece to effect a deformation of the material of the workpiece;
roll-forming teeth on the surface to be worked on the workpiece during the forcible movement of the workpiece and the tool until the smallest distance between the axes of the workpiece and the tool is achieved;
moving the workpiece and the tool away from each other, said movement being divided into an initially slow movement followed by a quick movement.

24. A method according to claim 23, wherein the movement of the workpiece and the tool toward each other terminates in a dwell at the smallest distance between the axes of the tool and the workpiece.

25. Apparatus for forming teeth on the peripheries of gear blanks by rolling, comprising:
first rotary means for mounting a gear blank for rotation about an axis of rotation;
second rotary means comprising a tool mounted for rotation, said second rotary means having a plurality of teeth around the periphery thereof;
drive means for at least one of the first and second rotary means;
means for changing the spacing between the axes of said first and second rotary means; and
means for radially and laterally progressively roll-forming each tooth on the periphery of each gear blank in response to said change in the spacing between the axes of said first and second rotary means.

26. A gearlike tool for use in machines for forming teeth on the peripheries of gear blanks by rolling, comprising:
a rotary member in the form of a gear having a plurality of tool teeth around the periphery thereof, the face width of one tool tooth being less than the face width of the gear blank;
said tool teeth being circumferentially and laterally spaced to laterally incrementally roll form each tooth on the periphery of said gear blank, the sum of the widths of the tool teeth being at least as wide as the gear blank.

27. A gearlike tool for use in machines for forming teeth on the peripheries of gear blanks by rolling, comprising:
a rotary member in the form of a gear having a plurality of tool teeth around the periphery thereof, each tool tooth having at least one effective surface width which is less than the width of said gear blank, said effective surface widths on adjacent tool teeth being circumferentially and laterally spaced, the sum of the effective surface widths on a plurality of said tool teeth being equal to at least said width of said gear blank.

28. Apparatus according to claim 25, wherein said tool has a cylindrical shape.

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