United States Patent

Dohmann

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[54] **METHOD FOR MANUFACTURING BEVEL GEARS**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. Nos. 788,434, Jan. 2, 1969, abandoned, and Ser. No. 15,807, March 2, 1970, abandoned.

[52] **U.S. Cl.** **72/352,** 29/159.2, 72/359, 72/377

[51] **Int. Cl.** **B21k 1/30**

[58] **Field of Search** 72/352, 358, 359, 377; 29/159.2

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[57] **ABSTRACT**

A method for manufacturing bevel gear is disclosed according to which a workpiece is prepared for placement into a suitable die and to have convex contour tangent to the cone defined by the root circles of the bevel gear to be made, the axial end face of the workpiece has diameter about equal to or smaller than the smallest root circle of the bevel gear.

14 Claims, 5 Drawing Figures

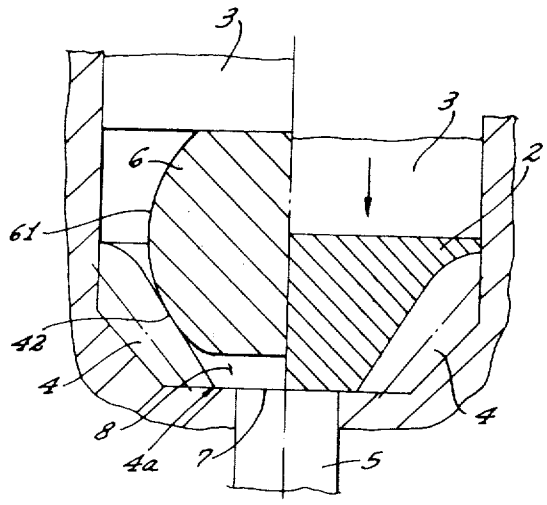


Fig. 1

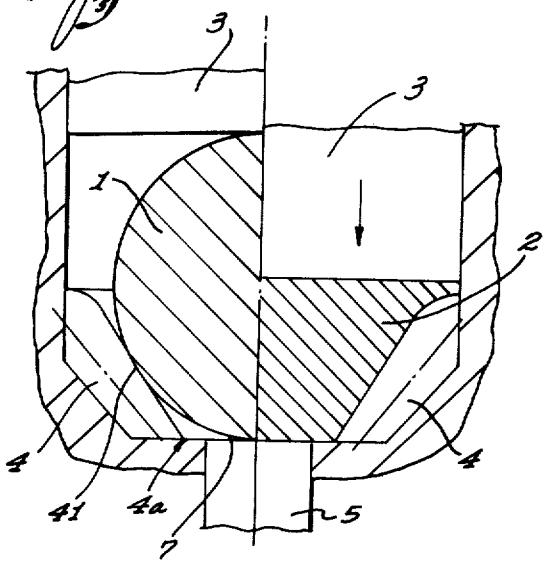


Fig. 2

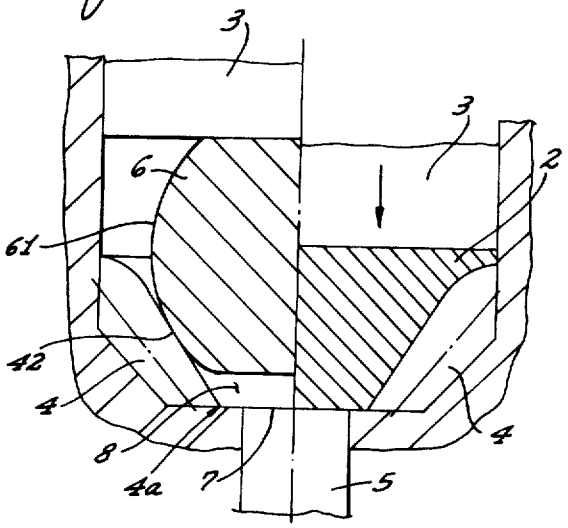


Fig. 3

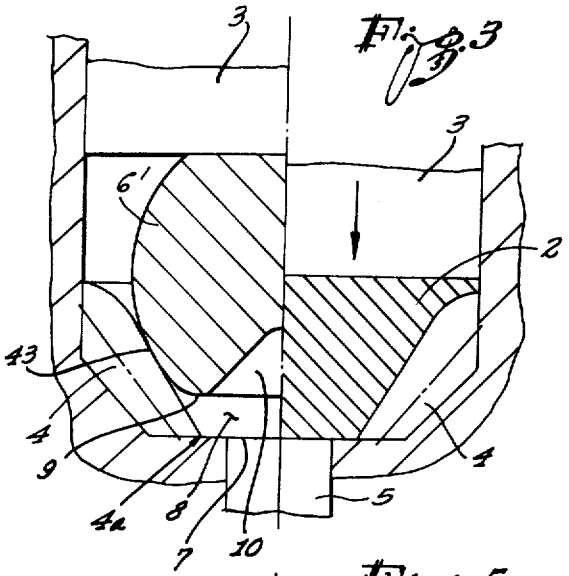


Fig. 4

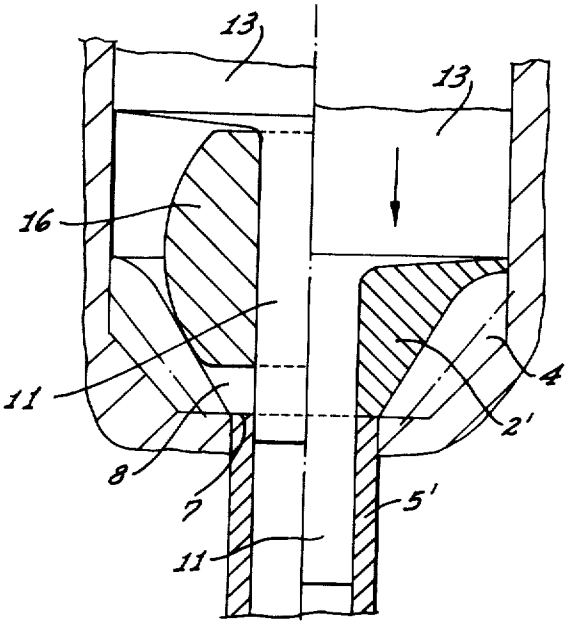
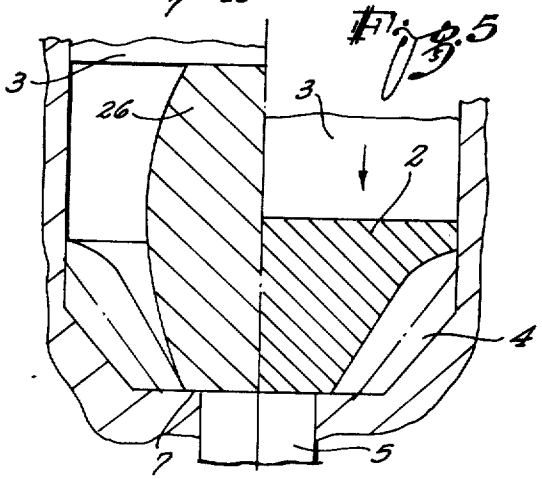


Fig. 5



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METHOD FOR MANUFACTURING BEVEL GEARS

This is a Continuation-in-Part application of applications Ser. No. 788,434, filed Jan. 2, 1969, and Ser. No. 15,807, filed Mar. 2, 1970, both now abandoned.

The present invention relates to a method and process for manufacturing bevel gears by forming a metallic bank in a die, the die cavity of which having contour of a bevel gear.

It is already known to hot forge a metallic workpiece to obtain bevel gears, hot forging being carried out by means of a tool which includes punch, die and counterpunch. The unworked piece (blank) has a cylindrical configuration at a diameter equal to or smaller than the smallest inner diameter of the die as determining the shape of the teeth. Furthermore, the end portion of the cylindrical blank, as facing the die bottom, is to be heated to obtain a higher temperature than the remaining portion of the blank. This method and process has been practiced already for several years and has gained some technical significance; the process and method has, however, a number of disadvantages.

Hot forging described exhibits, for example, the disadvantage that the preparation of the workpiece as an intermediate is already rather expensive as it can be produced only through lathing. Another disadvantage is to be seen in that nonuniform heating as resulting in an elevated temperature of one side of the workpiece is rather difficult to obtain. Moreover, forging at the required temperature results in production of scale and this, in turn, creates rather considerable difficulties as the formation of the scale increases tolerances and reduces accuracy. Particularly, peak-valley height of the surface is detrimentally affected by formation of scale. The layer of scale has usually thickness in the order of magnitude approximating or even exceeding required gear tolerances. Formation of scale can be avoided only if the entire process is carried out in a protective gas atmosphere which requires considerable expenditure and is rather expensive accordingly.

Another difficulty arising from utilization of hot forging is that during cooling of the forged gear wheel, from forging temperature to room temperature, the gear contracts and its dimensions are reduced accordingly. It follows that the tool itself must compensate that change in dimension by providing predistortion for the gear to be made. However, even them, it is still difficult to manufacture bevel gears in that manner so as to obtain accuracy and tolerances corresponding to accuracy and tolerances obtainable by making bevel gear by means of cutting. This fact has led to employment of forged wheels only in those kinds of transmissions having correspondingly low requirements as to accuracy, for example, differential gear of the rear axle of trucks or the like.

In order to avoid these various deficiencies outlined above numerous attempts have been made to press bevel gears at room temperature, using tooling that is capable of providing bevel gear form. Cold working has the advantage over hot forging that dimensions are not changed through shrinking of the gear, particularly after pressing, and heating is not involved in the process. Moreover, the undesired formation of scale is likewise avoided. Pressed gear, however, deviate from the desired dimension due to elastic deformation of the tool during pressing. Nevertheless, these inaccuracies are considerably smaller than shrinking of a forged wheel.

It has also been suggested to cold form the metallic unworked piece in a tool to provide bevel gear, which tool comprises a die having contours to impart the required gear configuration upon the workpiece, and the tool includes a press punch as well as a counterpunch. The workpiece may be prepared as blank with or without bore, has cylindrical configuration, and its outer diameter approximates the largest inner dimension of the die. The axially operating punch is supposed to press the blank from above into the tapering bevel gear die cavity. The basic idea behind this mode of operation is that the die is filled with material resembling the flow of material in the shaping zone of a forward flow or extrusion press method. However, tests have shown that the geometry of forming and shaping the material particularly in the tooth forming cavity portion of the die and the resulting flow characteristics and behavior of the material within the cavity does not permit complete filling of all parts thereof.

Another method has been suggested according to which workpiece is prepared as conical blank to be formed to a bevel gear and having a surface which matches approximately the root cone of the teeth of the bevel gear. The material is supposed to flow into the tooth forming cavity portions of the bevel gear die and over the entire length of the form under the influence of pressure that is axially applied. However, it was found that this method is likewise not practicable. The material flows first into the tooth cavities of the die in the upper (wider) region of the gear because they offer comparatively little resistance against the inflowing material due to the rather large cross section of that portion of the die and as compared with the smaller cross sections at the tapering end of the bevel gear. Now, as the material meets the die wall in the range of the large gear wheel diameter (base of the cone) the pressing operation is actually terminated therewith because of the corresponding steep increase of pressing force at that point.

The problem to be solved with the present invention is to deviate from the line of thought underlying previous methods and processes for making bevel gears and to teach a process for making such bevel gears without additional and supplementing steps such as the employment of a protective gas atmosphere or fine finish of the formed gear to obtain desired dimensions.

In accordance with one aspect of the present invention in the preferred embodiment thereof bevel gears are to be made from a metallic blank in an appropriately shaped die, in that the blank, as an intermediary product, is prepared to have convex contour along an axially symmetrical, circumferential surface with rotational symmetry in relation to the axis of the die into which the blank is placed. The resulting bulging configuration is to have proportion so that the blank when inserted into the die will extend not further than the plane of the smallest root circle as defined by the closed bottom of the die; the surface area of the blank closet to the plane of that root circle is to have dimensions not or barely exceeding the smallest root circle, and in the preferred form the blank is to be tangent to the inner (frusto) cone surface of the groove forming projections of the die, above the bottom of the die.

The press forming step proper is preceded by a preparing step for the unworked piece so as to provide an intermediate product type blank having these configurations. The intermediate product is manufactured directly in the appropriate shape or by shaping. The largest diameter of the bulging blank may be approximately in the axial level of the largest diameter of the toothing as provided by the die, while the smallest diameter of the convexly shaped intermediary, also relative to the cylinder axis, preferably corresponds, approximately, to the smallest frusto cone diameter, corresponding to the smallest root circle of the bevel gear toothing as provided by the die. The convexly shaped surface of the intermediate may be tangent to the inner cone surface of the die in approximately the (axial) semi-height of the toothing.

A previously prepared blank is placed into the die, and subsequently, pressure force is applied, there being provided punch and counterpunch to press the blank into the die cavity so as to coin the bevel gear. The press forming step may be a cold working step or may be carried out at elevated temperatures, whereby it was found that for the more convex surface (smaller radius of curvature) of the bulge, the temperature can be lower. In accordance with another feature of the invention for higher heating temperatures the convexity of the intermediary is reduced, so is its diameter, while the height thereof is chosen somewhat larger (as the volume is constant for a particular gear to be made).

It was found that successful employment of material working and forming depends to a considerable degree upon particulars of the shape of the blank and that successful employment of the working and forming process requires particular relation to the geometry of the die cavity which will result in

satisfactory final products. The intermediate workpiece to be prepared in this manner as particularly shaped blank permits filling of the die cavity beginning with cavity regions at the small bevel gear diameter. If the unworked, intermediate product blank has such configuration, the die is filled completely even if there is cold-working, as the flow of material is oriented to originate from the small diameter region of the bevel gear die. The forces applied can be comparatively low so that the die is neither destroyed nor undesirably expanded during the process of pressing the workpiece into the die. It is, however, required that the die is inserted in a particular armoring.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention, it is believed that the invention, the objects and features of the invention and further objects, features and advantages thereof will be better understood from the following description taken in connection with the accompanying drawings in which:

FIGS. **1**, **2**, **3**, **4** and **5** show different examples for practicing the present invention. Each figure shows a cross section through tool and blank but in a biparted manner; the left-hand side of each figure shows a cross section through the tool and a blank after insertion in the die but prior to press forming, for example, by warm or cold working; the right-hand portion of each figure is cross-sectional view right after working, before ejection.

FIG. **1** illustrates in particular the cold-working of a ball-shaped, unworked blank **1**, having been prepared as an intermediate product out of which a bevel gear is to be manufactured. Thus, the intermediate product is presumed to have been manufactured in a preparing step, resulting in a ball which meets the requirements for such product in accordance with the general rule, requiring axial symmetry and convex profile of the rotationally symmetrical surface in any axial plane. Reference numeral **3** denotes the punch coacting with a die **4**. The die has configuration corresponding to the required shape of a bevel gear and includes ridges or projections for forming the grooves of the bevel gear. The apices of these projections define a cone establishing the root circles of the gear. The ball-shaped blank **1** is tangent to the ridges of the die at a circle **41** or elemental frusta cone above the bottom **7** of the die. An ejector punch **5** is positioned as the bottom **7** of the die. That bottom is also defined by the smallest root circle **4a** of the die.

The method in accordance with the present invention can thus be carried out by using ball-shaped, intermediate product blanks. Alternatively, barrel-shaped blanks as intermediate products or frustoconical pieces merging into ball or barrel-shaped configuration can be used. However, after many tests it was found that a barrel-shaped blank is preferred and has added advantages, particularly regarding the power requirements for producing the desired deformation and shaping. The required power for the die punch is smaller in case a barrel-shaped or a frustoconical blank is used than in case of a ball-shaped one. In other words, a barrel-shaped blank is better capable of filling out the die upon working, e.g. cold working, so that extrusion flow of the blank material fills the die completely and requires minimum force and power. Moreover, it was found that a barrel-shaped blank can be manufactured more evenly and more economically than ball-shaped pieces.

FIG. **2** shows the cold-working of a barrel-shaped blank **6** as intermediate product, out of which bevel gear **2**, similar to one in FIG. **1**, is to be manufactured. This, then, is actually the preferred mode of practicing the invention. In view of the fact that the cross section of the figure can be taken in any plane which includes the common, dash-dot axis of die and blank, the general rule concerning convexity in each such plane is fulfilled. Moreover, the convexity of the circumferential surface of the unworked blank **6** is selected such that upon placing blank **6** into die **4**, a space **8** remains between the lower, downwardly facing, flat surface of blank **6**, and the bottom **7** of the die. The tool for pressing blank **6** into the desired shape includes, furthermore, also a press punch **3** and a counter-punch **5**.

The power requirements for deforming the blank can be reduced further, particularly near the bottom of the die, if in accordance with a further improvement of the invention, die diameter of the surface of the barrel-shaped blank facing die bottom **7** is, approximately at least, equal to the diameter of the smallest tooth circle of the die. Moreover, the curved contour of barrel shaped workpiece **1** sits on the ridges of the die cavity, defining the grooves between teeth i.e. the root bottoms of the bevel gear to be made, along an elemental frusto-cone **42** that is above the bottom of the die **1** in about a semi-height of the bevel gear.

High friction forces between die and blank occur at the bottom of the die, particularly at the beginning of the forming process. Accordingly, the material of the blank will be compacted near the bottom of the die more readily than in other areas thereof. As a consequence, the tooth corners near the bottom of the die do not completely fill with material. Such undesirable result can be avoided if the blank is provided with a pyramidal or frusto-pyramid-shaped indentation, where facing the die.

FIG. **3** shows the cold-working of a barrel-shaped blank **6'**, into a bevel gear. Blank **6'** is additionally provided with a pyramid-shaped indentation **10** projecting inwardly from the lower surface **9** facing the bottom of the die. Also, in this embodiment there is punch **3** and an ejector **5**.

The selection of the dimensions of this indentation is, per se, uncritical, but it is necessary that the indentation is not too small. A depth for the indentation of approximately one-third of the total height of the blank and a base diameter of the indentation which approximately equals the diameter of the smallest root circle **4a** in the die have been found to produce favorable results. The blank fits on the groove and root forming projections on the die along circle **43**.

In addition, the convexity of the circumferential surface of blank **6'** is selected such that upon inserting work piece **6'** into die **4**, again a space **8** remains between work piece **6'** and the bottom of die **7** which is not filled with material prior to cold working punching.

A selection of the circumference and contour of the blank in that manner can be made in lieu of or in addition to the provision of the above-mentioned indentation **10**. The dimensions concerning the convexity of the blank should be selected in that manner, so that a space **8** remains particularly if the depth of the teeth of the bevel gear is within the usual limits. In case of unusually large depth for the teeth, the unfinished work piece should be prepared as intermediate produce by employing both measure, i.e., indentation **10** and convexity to leave space between the work piece and the bottom of the die.

A still better degree of filling the tooth corners of the die next to the bottom thereof can be obtained if the bottom of the die is provided with a convex protrusion which is introduced into indentation **10** of the unfinished work piece during the cold-working process.

Previously it was considered that the axial bore of the bevel gear could be produced by stamping or cutting, requiring a separate step accordingly. In accordance with the present invention, however, it is possible to include the making of the axial bore in the press working process. For this it is required to form a central bore in the unworked piece when preparing it as the intermediate product and to provide the front face of the punch with a spindle-like pin.

FIG. **4** illustrates the press working of a blank **16** wherein the making of a bevel gear is to include the manufacturing of an axial bore in the bevel gear. For this, the barrel-shaped blank **16** is provided as an intermediate product with an axial bore. A cylindrical pin **11** extending from the particular punch is inserted in this central bore of blank **16**. The outer diameter of pin **11** corresponds to the diameter of the axial bore of blank **16**. The latter bore can be selected approximately equal to or smaller than the inner diameter of the final, axial bore in

the bevel gear. The remarks previously made are valid here in an analogous manner. In this embodiment there is also a space 8 which is free from material prior to punching and which extends between bottom 7 of die 4 and the downwardly directed surface of the work piece 16. Also in this embodiment there is an ejector 5'.

Assuming the bevel gear is not required to meet exceedingly high requirements for accuracy and tolerances, they may be produced out of the unfinished-intermediate blank in one step. If, however, the tolerances are more critical, it is of advantage to cold-work the work piece in two steps. An annealing step is carried out between the two cold-working steps, for purposes of recrystallization of the material.

FIG. 5 shows a blank 26 which stands directly on bottom 7 of the die and is higher than the die. The working temperature should be about 650° C.

After having described the contour of various workpieces and intermediaries with the aid of which the invention can be practiced with advantage, the processes involved during press forming the various blanks for making bevel gears will be discussed now in detail, for a better understanding of the invention. The shape of the intermediate product and blank has been particularly selected so that during working the material is caused to flow first along the incremental frusto-conical surface along the points of direct conduct between workpiece and the tooth-root defining projections of the die as projecting into the die cavity. These projections define the root cone of the bevel gear. Initially, the workpiece engages that part of the die only in isolated points such as 41, 42, etc. These points have relative positions above the bottom of the die.

As punch 3 provides force in axial direction, the material begins to flow in axial direction, i.e., from in between these incremental areas of engagement with the die in axial direction and into the tooth forming cavity extensions of the die. It is now important that the relative position of that circular surface of engagement is selected that the material can reach the portions of the die cavity corresponding to the smallest diameter portion of the tapering toothing near the bottom of the die, by *axial* flow. This way the region of the cavity corresponding to largest form resistance is rather easily filled with material, because that material reaches that bottom area of the die along the shortest flow path, at minimum increase in hardening and rigidity.

As punch 3 progresses further in axial direction, towards and into the die cavity, material then flows essentially radially into the tooth forming cavities of the die which material undergoes progressively hardening due to continuously increasing degree of deformation, but the material thusly flowing is offered increasing tooth cross sections due to the bevel shape. The tooth forming cavity portions, thus, fill first near the tapering bottom end of the die and from there progressively up towards the large diameter portions of the bevel. Concurrently, some material flows in radial outward direction along the front face of punch 3 but that radial flowing material hits the outer die wall of the die cavity at largest diameter *only after* the tooth defining cavities have in fact been filled completely. It is, thus, possible to obtain complete filling of each and every tooth forming cavity during a single punch stroke.

In case requirements concerning tolerances and accuracy of dimensions for the bevel gear are rather high, it is advisable to provide forming in two steps and in between the two press steps recrystallizing annealing and scouring is carried out.

The blank flows under the influence of an axially effective punch force in the manner described if the convex contour of the blank engages the inner cone corresponding to frusto-conical contour of the roots of the teeth of the bevel gear, above the bottom of the die, for example, at about the semi-height thereof, while the smallest diameter of the blank approximates or is smaller than the diameter of the smallest work circle of the gear. Exact matching of the blank, to the desired bevel gear contour, requires rather accurate preparation of the dimensions of the blank. The dimensions of the blank depend upon the apex angle of the cone defining the tapering contour of the bevel gear; the module and the outer diameter of the gear wheel to be made are additional factors. The flow conditions are to be as described, permitting filling of the tooth defining die cavity portions for the smallest gearing portion by axial flow of the material and these cavity fill progressively from narrower to wider diameter portions of the taper. These flow conditions can be approximated by blanks having barrel shaped configurations or having ball or barrel contour which merges into a frusto-conical configuration.

The process can be carried out as cold working process but the forces required for forming can be reduced if the blank is heated prior to working. The resistance of the material against working and change in form, i.e., its mean tensile strength, is reduced while its deformability is increased. Filling the tooth-establishing cavities in the die with inflowing material is, however, not as favorably affected by the resulting reduction in the resistance of the material against change in form in spite of the lowering of the required press force. It follows that this nonuniformity of response as to increase in temperature of the blank requires additional measures. It was found that the convexity of the blank should be reduced for higher temperatures of forming. In other words, the radius of curvature of the contour of the blank in axial plane should be chosen larger for higher working temperatures. For constant volume of the blank (and gear), this requires reduction in diameter and increase in height if the smallest diameter dimension of the blank is to approximate the smallest root circle of the bevel gear.

Matching the contour of the blank in this manner to flow conditions at higher temperature permits employment of the method at temperature up to forging temperature of about 1,200° C.

The invention is not limited to the embodiments described above but all changes and modifications thereof not constituting departures from the spirit and scope of the invention are intended to be included.

I claim:

1. A method for manufacturing bevel gears comprising the steps of:

providing a die having a cavity with contour to obtain a bevel gear, the die having groove forming projections defining a cone corresponding to the roots of the gear to be made, there being a smallest root circle defined in the axially facing bottom of the die;

preparing a blank with a circumferential surface having axially rotational symmetry in relation to an axis, at least a portion of the surface being convexly-shaped in any plane which includes the axis, the surface of the blank which faces and is closest to the bottom of the die along the axis thereof when inserted, having dimensions about equal to or smaller than the smallest tooth root circle of the die, the blank, when inserted into the die, projecting therein not farther than the bottom; and

working the thus prepared blank by using the die and press forming the blank into a bevel gear.

2. The method as defined in claim 1, wherein said blank is being prepared to have convex outer contour to be seated on the cone above the bottom of the die.

3. The method as in claim 1, the convexity of the blank selected so that upon coaxial placement of the blank into the die, the convex contour of the blank is about tangent to the axial semi-height of the gearing to be provided by the die, while the largest diameter of the convex workpiece is at about the level of the largest gear diameter as defined by the die.

4. Method as in claim 3, convexity of the workpiece being selected so that upon placement thereof into the die, the axial end face remains in spaced apart relation from the bottom of the die, prior to punch pressing.

5. The method as defined in claim 1, wherein the blank is barrel shaped, and the diameter of the surface thereof which will face the die upon insertion therein, is approximately equal to the smallest tooth root circle of the part of the die providing shaping of the teeth of the gear.

6. A method as set forth in claim 1, the preparing step including the providing of convexity to obtain a barrel shaped blank such that a space free from material remains between the workpiece upon insertion into the die and the bottom of the die.

7. A method as set forth in claim 1, the preparing step including the providing of convexity to the blank so that the blank sits on the cone above the bottom and a space free from material remains between the workpiece upon insertion into the die and the bottom of the die.

8. A method as set forth in claim 1, the working step carried out in two consecutive steps, with an annealing step in between.

9. A method as defined in claim 1, comprising the additional step of preparing the blank with a centrally located indentation in the surface intended to face the bottom of the die during the working step.

10. A method as set forth in claim 9, the working step including the introducing of a protrusion into the indentation.

11. A method for manufacturing bevel gears comprising the steps of:

preparing a workpiece with a circumferential surface having axially rotational symmetry in relation to an axis and being convexly shaped, at least in parts, and in any plane which includes the axis; placing the workpiece into a die so as to extend not further than into the plane of the smallest root circle in the bottom of the die to be used; and

working the thus prepared workpiece by using said die having a bevel gear axes to form a bevel gear, the workpiece being positioned with its axis of symmetry coaxial to the bevel gear axis of the die.

12. The method as in claim 11, the preparing step including preparing the workpiece to be disposed on root forming ridges of the die, whereby a free space remains between the workpiece and the bottom of the die.

13. The method as in claim 12, the workpiece about tangent to the semi-height of the gear to be made.

14. The method as in claim 12, the workpiece being barrel-shaped.

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