METHOD FOR THE COLD FORM GENERATING OF CYLINDRICAL WORKPIECES

Fig. 4

Fig. 5

Fig. 6

Fig. 7

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METHOD FOR THE COLD FORM GENERATING OF CYLINDRICAL WORKPIECES

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There are several methods for producing gear teeth without cutting.

According to one of these known methods two opposite profiled racks are tangentially brought into engagement with a workpiece rotating at a predetermined ratio to the rack movement in order to generate the desired profile. However, this method only admits small profile depth and lengths, and bending stresses are set up in the root of the tooth during the generation due to unavoidable deformation stresses. These bending stresses may result in the formation of cracks in the root zone as the profile is pressed simultaneously over the whole length of the toothing to be produced.

Another known method makes use of cold form generating rolls rotatably mounted in a rotating head and brought in rapid succession in and out of engagement with the rotating workpiece slowly fed in axial direction. This method admits normal tooth depths; however it requires for each tooth number of the same pitch a corresponding thread roll having the shape of the tooth space, as there is no rotating movement on account of the momentaneous and very short engaging length. It is therefore difficult to produce accurate profiles by this prior method. Moreover, when producing odd numbers of teeth with two opposite tools, the generating rolls must be staggered by ¼ of the pitch. Besides the distortion of the generating roll profile a force is produced in the axis of the workpiece which may reduce the accuracy of the generating operation.

It is a prime object of the present invention to provide a method for the cold form generating of cylindrical workpieces by means of generating tools moved relatively to the workpiece comprises the steps of imparting to the generating tools a movement in a plane comprising the profile track to be worked, directed towards the middle axis of the workpieces, of smaller dimension than the height of the profile to be worked and adapted to form the required profile without cutting and the steps of simultaneously imparting to the workpiece about its longitudinal middle axis a rotary generating motion determined by the movement of the tools, the nature of workpiece and of the profile to be produced, and of producing a relative feeding motion in axial direction of the workpiece between the latter and the tools.

By this combination of press and generating motions according to the invention it is possible to produce tooth surfaces of precise involute shape, for instance with a basic rack tool form, provided that the workpiece has favorable cold working characteristics. The tools used for instance for producing involute toothings may be generating worms with basic rack form. The tools are situated concentrically to the axis of the workpiece to be formed and effect rapid, peripheral movements.

In order to effect the generating operation the tool receives a feeding motion, i.e. a rotating or a repeating, axial motion or both together; this feed is positively coupled to the rotation and to the axial feed of the workpiece in a ratio depending on the number of teeth and on the required surface quality of the profile to be produced.

Other features and advantages of the invention will become apparent from the description, now to follow, of preferred embodiments, given by way of example only, and in which reference will be made to the accompanying diagrammatical drawings in which:

FIGURE 1 shows a sectional view through the axis of the workpiece and a partial cross-section of a tool holder along the line I—I in FIGURE 2.

FIGURE 2 shows a partial longitudinal section through three tool holders in star arrangement about a cylindrical workpiece shown in cross-section.

FIGURE 3 shows a partial view of the produced toothing for the explanation of generating steps.

FIGURE 4 illustrates an arrangement for producing gears with straight spur gears by means of two opposite tools showing the tool in a cross-section, along the line IV—IV in FIGURE 5.

FIGURE 5 is a cross-section along the line V—V in FIGURE 4 of the same arrangement as in FIGURE 4.

FIGURE 6 shows the disposition of the tools as used for producing straight spur gears in the arrangement of FIGURES 4 and 5, seen in the direction of the arrow VI in FIGURE 4, and

FIGURE 7 shows, in a view similar to that of FIGURE 6, the disposition of the tools as used for producing helical spur gears.

Generally speaking when working according to the method of the invention, the outer part of a cylindrical workpiece A of cold worked metal is repeatedly exposed to the action of several generating worms 1, which execute a rapid movement in direction to the axis B of the workpiece A in order to produce the desired profile on the workpiece, this profile being formed by the generating or rolling motion between the rotating workpiece A and the tool T.

This movement of each tool consists of an oscillation in direction of the axis X, i.e. in the longitudinal direction of the toothing to be produced and simultaneously in an oscillation in direction of the axis Y which extends radially to the workpiece A. Thus, these tools execute a movement C relative to the workpiece (FIGURE 1) whose trajectory has the shape of a flat ellipse mounting somewhat on the disengaging side.

In FIGURE 1 the generating worms 1 are mounted on pivoting and axially swinging tool holders 3 the axis of revolution of the worms being perpendicular to the swinging axis Y which is at the same time the tool holder axis. The tool holders 3 are mounted in a housing (not shown) so as to be slidable and pivotable about the axis Y; their swinging movement is produced mechanically in a not represented manner.

The tool holder axis Y may be perpendicular or inclined to the axis of the axis B of the workpiece A, the axis Y of the tool holders 3 always intersecting the axis B in one point.

On account of the movement C and of the resulting intermittent engagement of the workpiece by the generating worms, the latter roll on the rotating workpiece; these rotations about their longitudinal axis are synchronized through the shafts 5 which are interconnected in a gear box 4 through not shown gears. The sense of rotation of the generating worms is opposite to that of the movement C as shown by arrows in FIGURE 1. During the generating operation the rotating speed of the worms 1 is a whole number multiple of the rotating speed of the workpiece A, i.e. for each complete revolution of the workpiece each worm 1 effects several
complete revolutions namely at least one for each groove to be produced on the workpiece A.

During the generating operation the workpiece A is displaced in direction of its axis B by an axial feeding in direction G. This axial feed may be produced mechanically, electrically or hydraulically in a manner known per se. Thus, the workpiece A in addition to its rotation Y only fed between the moved profiling worms 1, whereby the latter first produces small recesses which are increased in size as the operation proceeds until the desired profile is generated. The continual rotation and the axial feed together with the corresponding movements of the worms 1 produce by the pressure in the border zone of the workpiece A a gear toothing which exhibits a very accurate true running and an outstanding surface quality of the tooth flanks and faces.

The clamping device such as a mandrel or a collet carrying the work A is mounted just as in automatic lathes on a spindle which in turn is supported on a slide being slidable on the machine bed along the profile to be produced. Profile lengths corresponding approximately to the stroke of the slide may be executed. Thus, it is possible to produce long profiled bodies which are cut up later on into separate sections. Of course, it is also possible to clamp several workpieces simultaneously on a workholder as it is customary in the production of gears.

FIGURE 2 shows by way of an example an embodiment for generating gears from a workpiece A by means of three tool holders 3 disposed in a starlike arrangement. The axes Y of these holders 3 intersect in one point of the axis B of the work so that their bearings have no radial forces to take up. The three angles α, β and γ between the axes Y differ from each other by an amount which can be from one angular second to 15 angular degrees. This irregular division results in an automatic correction of the profile being formed on the workpiece A, if the latter has a heterogeneous structure and as a result thereof has different hardnesses at different points thereof. As shown schematically in FIGURE 2 the rotation of the generating worms is positively synchronized by means of shafts 5 and gears in.

In order to produce a spur gear by means of the device according to FIGURE 2 the proceeding is the following:

A cylindrical bar, e.g. a steel rod serves as workpiece A whose outer diameter (FIGURE 1) corresponds approximately to the pitch circle of the gear to be produced. The workpiece is clamped in the clamping device; then the tools, i.e. the generating worms 1 are radially set so that the distance between the tooth crest of the tool at the inner end of the stroke thereof in the sense of the axis Y, corresponding to the position of these worms shown in FIGURE 1 and the workpiece axis B corresponds to the root circle S of the gear to be produced. Thereupon the tools are moved in such a manner that they execute their movements C in the plane which contains the profile trajectory to be produced. At the same time the work piece receives a feed movement towards the working area being situated between the tools and a rotation about its axis B being synchronized with the movement of the tools with the designed number of teeth. This rotation is transmitted to the shafts 5 and therefore to the tools by means of a dividing and change gearing (not shown). As soon as the front end surface of the workpiece enters the range of the operating tools, these form at each oscillation a gap into the workpiece. These gaps are distributed on account of the workpiece rotation over the whole circumference of the formed profile and produced by the feed of the workpiece as it will be clearly seen in FIGURES 1 and 3. The material m displaced by the formation of the grooves (FIGURE 3) forms the crest k of the tooth projecting beyond the pitch circle. By this rotary oscillation and feeding movement all tools take part in producing all tooth surfaces, thus insuring an absolute uniformity of the workpieces.

FIGURES 4–7 show a device producing at will straight spur gears (FIGURES 4–6) or helical spur gears (FIGURE 7). Two generating worms I carried by the tool holders 3 act on the workpiece again designated by A. The radial forces transmitted from the workpiece are compensated by a second work situated on the opposite side of the workpiece. The axes Y of the two tool holders 3 intersect with the axis B of the workpiece A so that no radial forces have to be taken up by the supports of the workpiece 1, when both tool holders 3 act simultaneously on the workpiece.

When producing straight spur gears (FIGURES 4–6), where all grooves are exactly parallel to the axis B of the work A, the axes of the generating worms are so pivoted (FIGURE 6) that the helix lines in a tangential section on the working side of the worms are parallel to the workpiece axis B, i.e. the generating worms must be pivoted by the angle λ which corresponds to the pitch angle of the worm profile.

Of course, also helical spur gears may be produced as shown in FIGURE 7. For this purpose the axis of the generating worms I are pivoted so that the axis B of rotation of the workpiece A that the helix lines in the tangential section on the working side of the worms 1 are aligned with the desired helix angle of the gear. The ratio of rotation between worm 1 and the workpiece A which is a whole number multiple remains the same according to the desired number of teeth; but the number of rotations of the work must be corrected according to the pitch angle and the feed just as with normal profiling machines.

For producing straight or helical spur gears on the device according to FIGURES 4–7 a cylindrical bar serving as a workpiece is automatically brought into a clamping device just as in FIGURE 2, whereby again the outer diameter d (FIGURE 1) corresponds approximately to the pitch circle dp of the gear to be produced. Then the generating worms are radially adjusted on the work as explained in the first example, and the amount of pivoting of the tool axis is such as according to a helical or a straight spur gear is required. Then the tools are set in motion. The tool and workpiece movements may be the same as in the first example, i.e. the work is rotated about its axis and is fed, whereas the tools execute the rolling movements C as explained with regard to FIGURE 1. This workpiece is generally produced in some definite toothing kinds it has been seen that the rolling movements of the profiling worms 1 may produce in the work A deviations from the desired direction of the teeth.

This is avoided by an additional, axial reciprocating movement of the generating worms together with an additional oscillating rotation synchronized with the above movement of the workpiece about its axis B.

This additional reciprocating movement of the tools takes place in a direction perpendicular to the desired direction of the teeth, i.e. perpendicular to the plane of the movement C (FIGURE 1). It is so set that the tool executes during each alternate movement C a "go" movement v (FIGURE 4) perpendicular to the plane C, whereas the "return" movement u takes place during the intermediate movements C.

Wherever the direction of the teeth deviates from the strokes u and v of the tool are so adjusted that they start before or after the tool has hit the work, i.e. before or after commencement of rolling; thus the tool acts longer on one flank of the gear than on the opposite one so compensating the deviation.

The length of the additional stroke u or v corresponds at least to the generating length originating from a work stroke in direction X (FIGURE 1), i.e. u or v = x tan φ, where x = stroke in direction X and φ = pitch angle of the generating worm.

The additional, oscillating rotation of the work piece
corresponds exactly to the strokes \( u \) and \( v \) respectively in the generating circle of the toothing to be produced.

The method described permits the execution of rolled profiles in the outer zone of a workpiece whereby it is possible to produce with one tool (generating worm with basic rack form) all possible numbers of teeth together with the so-called profile corrections (profile displacement). Therefore, it is no longer necessary as with the known prior methods to provide a special tool for each teeth number or each number group of teeth.

It is also possible to produce plane surfaces or separate grooves on the outside of a workpiece \( A \) if the oscillating tools feature the corresponding profiles and the work \( A \) is displaced along its axis \( B \) through the working area with or without additional rotation.

Of course, the method also is carried out by keeping the workpiece changed in axial direction and by imparting a feed to the profiling tools in direction of the profile trajectory.

We claim:

1. In a method of cold form generating of profiles on cylindrical workpieces, said profiles having raised and depressed portions progressing along the length of said cylindrical workpiece by moving cold forming tools relative to the workpiece, the steps of imparting to the cold forming tools movement in the direction in which the portions of the profile being formed extend as well as toward and away from the central longitudinal axis of the workpiece, said movement toward said central longitudinal axis being from the surface of the cylinder and for a distance less than the height of the portions of the profile being formed, simultaneously continuously rotating the workpiece about its central longitudinal axis, and simultaneously moving the workpiece in the direction of the longitudinal axis thereof between the tools.

2. The method as claimed in claim 1 in which said tools have identical profiles and the tools are moved simultaneously and in synchronism with each other.

3. The method as claimed in claim 1, in which said tools are each in form of a worm, and each tool is rotated about its own longitudinal central axis at a speed synchronous with the speed at which the workpiece is rotated.

4. The method as claimed in claim 1 in which said tools are each in the form of a worm, and each tool is rotated about its own longitudinal central axis, the portion of the movement which is in the direction in which the portions of the profile extend being movement parallel to the longitudinal central axis of the workpiece, whereby a splined shaft or a spur gear can be formed.

5. The method as claimed in claim 1 in which said tools are each in the form of a worm, and each tool is rotated about its own longitudinal central axis, the portion of the movement which is in the direction in which the portions of the profile extend being movement at an angle to the longitudinal central axis of the workpiece, whereby a helical gear can be formed.

6. The method as claimed in claim 1 in which said tools are spaced around the circumference of the workpiece at distances which differ slightly from each other, whereby irregularities in the shaping will be substantially eliminated.

7. The method as claimed in claim 1 in which each tool is a worm, and each tool is rotated about its own longitudinal central axis, the movement of each tool in the direction in which the portion of the profile extends and toward and away from the workpiece being in a flat ellipse which lies in a plane including a line corresponding to the direction in which the portion of the profile extends, the dimension of said ellipse in the direction toward and away from said workpiece being less than the height of the portion of the profile, said tools rotating in a direction opposite to the direction in which said tools move around said ellipse and at an average speed equal to the speed of the movement of said tools around said ellipse.

8. The method as claimed in claim 7 in which said tools are also moved parallel to the axis about which it rotates and said workpiece has superimposed on the continuous rotational movement thereof an oscillating rotational movement which is synchronized with the movement of said tools parallel to their own axes of rotation.

9. The method as claimed in claim 7 in which said worms are rotated around their own axes at a rate which is a whole number multiple of the rate of rotation of the workpiece.

10. The method as claimed in claim 8 in which the direction in which the profiles extend is helical and the rotation of said worms is synchronized with the movement of the workpiece in the direction of the longitudinal axis thereof.

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