

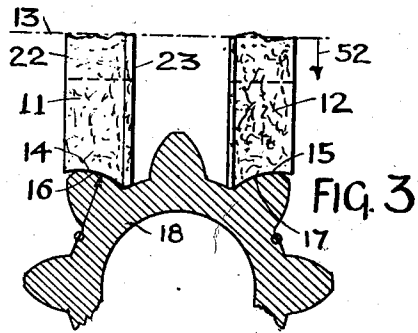
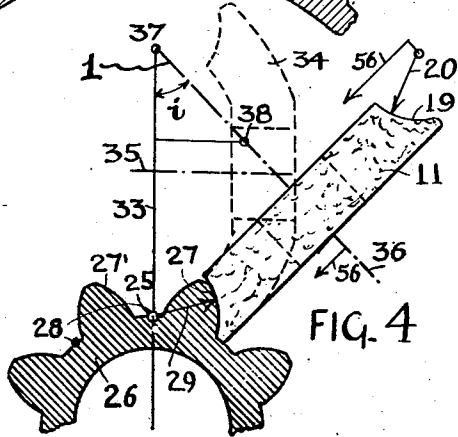
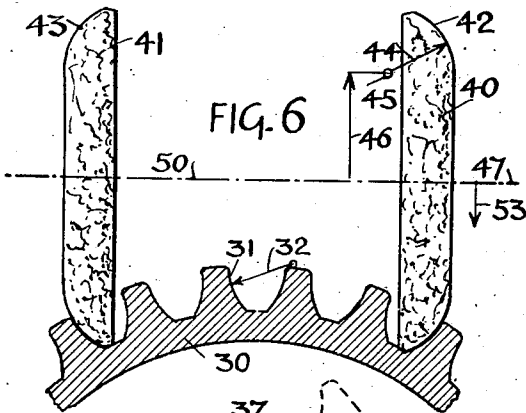
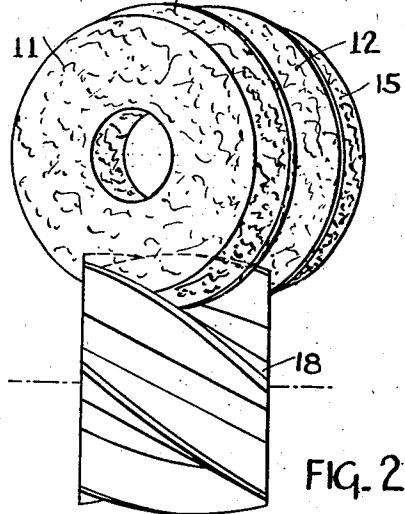
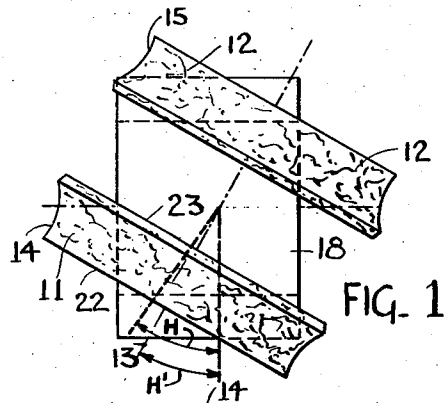
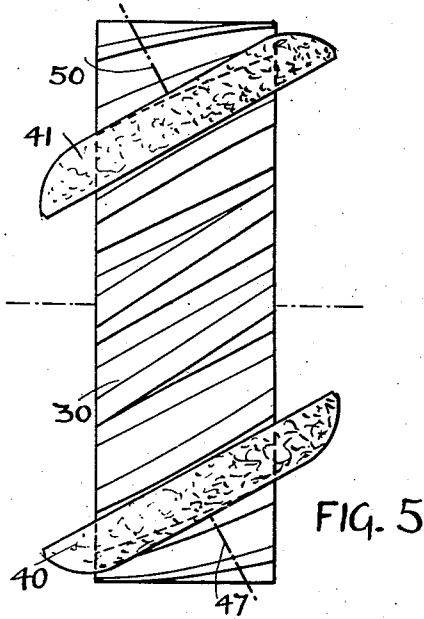
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1,858,568

METHOD OF GRINDING GEARS

Filed Sept. 25, 1926 2 Sheets-Sheet 1



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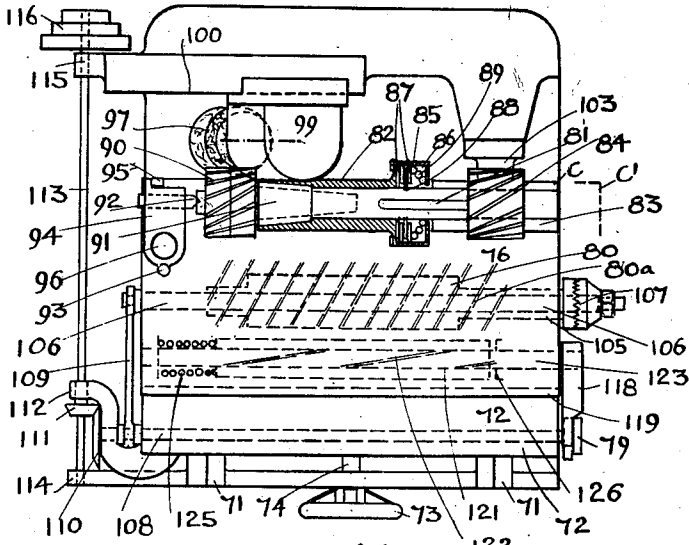


FIG. 7

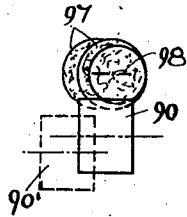


FIG. 10

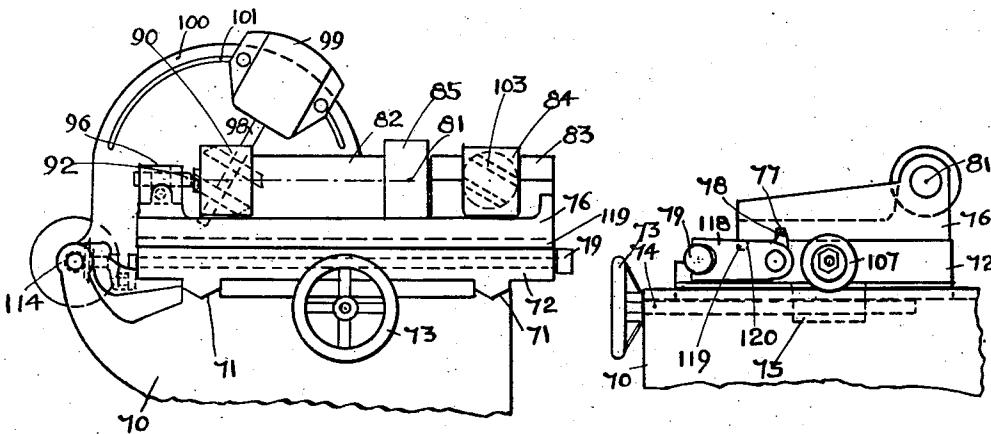


FIG. 8

FIG. 9

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METHOD OF GRINDING GEARS

Application filed September 25, 1926. Serial No. 137,792.

The present invention relates to methods of grinding the teeth of gears, namely straight teeth and particularly helical teeth or threads.

One object of the present invention is to devise a method of grinding the sides of gear teeth with a grinding wheel which may be trued to a single circular arc.

Another object is to devise a method of grinding teeth with a grinding wheel so positioned as to increase its rigidity and to increase the volume of its useful abrasive material.

A still other object is to devise a method of the said character, which employs a pair of grinding wheels rotatable about axes extending in the same direction.

A further aim is to provide a method for grinding the teeth of a pair of gears, which employs on one gear of said pair a grinding wheel having a convex circular grinding profile, and on the other gear of said pair a grinding wheel having a concave circular grinding profile.

Another object in view is to provide a method for grinding a pair of helical or herringbone gears with grinding wheels whose profiles are single convex circular arcs and single concave circular arcs respectively, the radii of said arcs being substantially equal.

Further objects will appear in the course of the specification and in the appended claims.

While my method is applicable to a great variety of gearing, one important application is to grinding helical and herringbone gears of the type disclosed in my application entitled "Helical gearing", filed November 2, 1923, Serial No. 672,254.

My invention will be explained with reference to the accompanying drawings, in which:

Fig. 1 is a plan view of a pair of grinding wheels in engagement with a blank, said wheels being positioned and shaped according to the present invention.

Fig. 2 is a front elevational view of the same, corresponding to Fig. 1.

Fig. 3 is a partial view of a pair of grinding wheels in engagement with a gear blank,

the view being taken in the direction of the teeth, which are shown in section.

Fig. 4 is a partial section perpendicular to the teeth of a blank, and a comparative view of grinding wheels of different positions.

Fig. 5 is a plan view showing a pair of grinding wheels of convex grinding profile in engagement with a gear blank, which latter may mesh with a pinion as shown in Figures 1 and 2.

Fig. 6 is a view of the grinding wheels shown in Fig. 5, taken lengthwise of the teeth, which are shown in normal section.

Fig. 7 is a plan view of a machine for practicing my method.

Fig. 8 is a front elevational view of the same.

Fig. 9 is a side view corresponding to Fig. 8.

Fig. 10 is a diagram explanatory of the operation of the machine shown in the Figures 7, 8, 9.

In Figs. 1, 2 and 3, 11 and 12 denote two coaxial grinding wheels rotatable on an axis 13 and provided with curved grinding surfaces 14, 15. These grinding surfaces are outwardly disposed and engage with opposite tooth sides 16, 17 (see Fig. 3) of different tooth spaces of a gear blank 18.

Preferably the grinding wheels are trued with known means, to single circular arcs, as indicated diagrammatically at 19 in Fig. 4, whose radius 20 is smaller than the outside radius of the grinding wheel.

Truing to a circular arc is a very simple operation, which can be performed with high accuracy and thus insures an accurate product.

It is further noted, that by positioning two wheels so as to grind on opposite tooth sides of different tooth spaces the grinding profile of the wheels can be made more inclined to a radial plane (22 or 23, Fig. 1 and Fig. 3) than when grinding both sides of a tooth space with a single wheel. This reduces deflections of the grinding wheels, and the grinding wheels are more similar to those used in cylindrical grinding, whose rigidity and efficiency is well recognized. For the same reason the wheels shown in Fig. 3 offer

more useful grinding material per tooth side than an abrasive wheel, which engages both sides of a tooth space simultaneously.

In comparison with flat grinding wheels, which grind with a plane side surface, the wheels shaped and positioned according to the present invention are more rigid, and offer more grinding stock, comparing wheels of equal diameters.

Fig. 4 is a section perpendicular to the teeth at a point 25, which is usually a point of the pitch surface. Fig. 4 has particular reference to the type of helical gearing above mentioned. In this gearing, the pinion 26 of a pair of gears is provided with teeth consisting entirely of addenda, and having circular tooth profiles 27 in normal section, whose centers 28 are located on the pitch surface. The gear, or larger member of the pair (30, Fig. 6) is provided with concave circular profiles (31), whose centers are also on the pitch surface and whose profile radii (32) are substantially equal to the profile radii 29 of the pinion.

It has been demonstrated in the application referred to, that teeth of this character contact with each other along a whole profile at once, unlike usual gears, namely along the profile (27), whose center (28) just passes through the radius (33) which connects the axes of the two gears. As the gears turn on their axes, the profile along which the contact takes place, moves axially of the gear, passing from one side of the face to the other.

In gearing of this type, a grinding wheel 34, indicated in dotted lines in Fig. 4, having a circular grinding profile 27, will contact with a pinion blank 26 along said profile 27, if its axis 35 is situated in the plane of the normal section, namely the plane perpendicular to the tooth helix at point 25 of the pitch surface. Axis 35 is perpendicular to radius 33 and is therefore inclined to the plane of the gear, that is a plane perpendicular to the gear axis, by the helix angle of the teeth; in other words by the same angle (H) as the teeth or threads are inclined to the straight generatrices of their pitch surface.

Preferably a grinding wheel (11) is differently and so positioned, that its grinding profile is more inclined to a radial plane. The axis 36 of such a wheel will then include an acute angle i with radius 33, and will therefore be less inclined to the plane of the gear blank than axis 35 of the wheel 34.

The inclination angle H' of axis 36 to the plane of the gear blank will now be determined. Angle H' is indicated in plan view Fig. 1, where also the helix angle H is shown for comparison.

Inasmuch as the latter plane intersects the drawing plane of Fig. 4 along radius 33, and is inclined to it by said angle H , the sine of inclination angle H' of axis 36 to said plane can be determined by plotting a unit distance

(1") from point 37 to point 38 on axis 36, and by determining the normal distance of point 38 from the plane of the gear blank. This normal distance divided by the said unit distance (1") equals $\sin H'$.

The distance of point 38 from radius 33 is $1'' \times \sin i$, and the normal distance of point 38 from the plane of the gear blank is therefore $1'' \times \sin i \times \sin H$.

Hence $\sin H' = \sin i \times \sin H$.

In Fig. 5 and Fig. 6 I have shown two grinding wheels 40, 41 having convex circular grinding profiles 42, 43. Profile 42 has a radius 4 and a center 45. It is noted that the center 45 of the profile is at a distance 46 from axis 47, which is smaller than the radius of the wheel 40, whereas the center 48 of the concave profile 19 of grinding wheel 11 (Fig. 4) is situated at a distance from axis 36 greater than the outside radius of wheel 11.

The axes 47, 50 of the wheels 40, 41 extend in the same direction, (see Fig. 5). The same holds true for the axes of the wheels 11 and 12 of Fig. 1 and Fig. 2. In the present case, however, the axes do not coincide, but are shifted apart axially of the gear by such a distance, that the wheels 40, 41 operate on the respective tooth sides at about equal axial position with respect to the gear blank.

Grinding with both wheels at about the same axial location on the gear saves in the length of axial feed, which is required for finishing the teeth. The saving is increasingly pronounced, the larger the diameter of the gear blank is in comparison with its face.

By positioning and shaping a pair of grinding wheels as shown in the drawings, namely so that the grinding profile includes a considerable angle with a radial plane, I gain the further advantage, that I may adjust both wheels in the same direction for truing. This adjustment is preferably effected at right angles to the axes of the wheels, in directions 52, 53 in Figures 3 and 6 respectively. The usual way of adjusting a pair of wheels in the art of grinding gears is in different directions on the two wheels, and not merely at right angles to their axes, but also axially or in an inclined direction.

The profile (19 in Fig. 4) of a grinding wheel may be trued on the side opposite to the grinding contact, and the truing device is then fed in the same direction 56, as the wheel, as known in the art, and twice as fast. Its feed corresponds to the reduction of the diameter of the wheel, whereas the feed of the wheel itself corresponds to the reduction of its radius.

The principles laid down are not restricted to the type of helical gearing above referred to, but can be applied to gearing in general. While in the mentioned special case a pair of gears is ground with grinding

wheels trued to convex and concave circular arcs respectively, of substantially equal radii, different truing radii may be used on gear and pinion in the general case.

The present method can be carried out in various ways and with various means, such as for instance with a machine as outlined in the Figures 7-9.

A frame 70 contains guide ways 71, in which a slide 72 is radially adjustable with a hand wheel 73. The latter is secured to a screw 74, which engages a nut 75 forming part of slide 72. On top of slide 72 a slide or table 76 is provided, which is movable in a plane. Its radial position is controlled by a slot 77 engaging with a tooth 78, whose angular position is determined by cams (79). The axial or lateral position of table 76 is controlled by a helical pinion 80, engaging with rack teeth (80a) of said table 76, so that tooth engagement is kept up in different radial positions of said table.

Slide 76 carries a spindle 81 held in suitable bearings 82, 83. Spindle 81 contains a master gear 84 of equal tooth number and equal lead as the blank, and a brake 85, which somewhat opposes free rotation of spindle 81. Brake 85 is preferably of multiple disk type, running in oil to give smooth action. Brake 85 consists of a housing 86 fastened to table 76, and containing a series of disks 87 which engage with internal splines of said housing and which alternate with disks 88 engaging with external splines of spindle 81. The various disks are under the pressure of a spring 89.

A blank 90 (or two, as shown) is placed on a taper arbor 91, which fits in a taper hole of spindle 81, and on its outboard end is held by dead center 92. Center 92 is kept in position by a spring (not shown) acting on a ball 93, which presses arm 94 against stop 95. Arm 94 may be swung about pivot 96, for introducing or removing the blank.

Blank 90 engages coaxial grinding wheels 97, which are driven through shaft 98 by an electric motor 99. For simplicity's sake several known details are omitted in the drawings, such as the truing device and the means for feeding the blank relatively to the grinding wheels. Motor 99 may be adjusted to the desired angularity (H') on a circular guidance 100, and may be fastened with screws engaging T-slot 101.

The operation of the machine is as follows:

Table 76 is moved back and forth axially, in the direction of spindle 81, by helical pinion 80. Near or at the end of each complete stroke, table 76 recedes under the influence of tooth 78, and the blank gets out of engagement and out of reach of the grinding wheels 97. It remains out of reach during the (axial) return stroke. If the working stroke is from right to left, Fig. 7, and the return stroke from left to right, then the

blank is being ground while moving axially from right to left, and it clears the grinding wheels while moving from left to right.

Fig. 10 shows the blank 90 in working engagement with grinding wheels 97, and in the dotted position 90' out of engagement, on the return stroke.

When grinding helical teeth, I always provide during the working stroke a feed between grinding wheel and blank in the direction of the axis of the blank and angularly about said axis. In other words, the blank performs a helical motion on its axis with respect to the grinding wheel.

During the working stroke, the master gear 84 engages with a stationary projection 103 in the same manner as a grinding wheel engages the teeth of the blank, or in another suitable manner. The master gear, and with it blank 90, are therefore turned, as they move in the direction of their axis, while brake 85 slides; and the lead of the master gear is reproduced on the blank. During the radial receding motion of table 76 the master gear 84 gets out of engagement with projection 103, and spindle 81 stops turning, prevented by brake 85. Spindle 81 starts to turn again only in the following working stroke, after master gear 84 and projection 103 have come in engagement again.

As the blank turns only during the working stroke, it turns in one direction only, and is therefore indexed in every stroke. The stroke is made of such length, that the blank is indexed by a full number of teeth, and that engagement between master gear and projection 103 takes place smoothly. This latter engagement starts earlier and lasts longer than the engagement between the blank and the grinding wheels.

Referring to Fig. 7, the working stroke starts about, when corner C of table 76 is in dotted position C'. If so desired, grinding contact may be made on one tooth even before the radial feed of table 76 has been fully completed, and after it has started, that is before and after the blank is at full depth position.

Pinion 80 is secured to hollow shaft 105, which receives oscillatory motion from concentric shaft 106 through a fine tooth clutch 107. The latter permits to adjust the axial position of table 76. Shaft 106 carries on its left end an adjustable crank pin, which is oscillated from a shaft 108 by a connecting rod 109. Shaft 108 is journalled on slide 72 and carries on its left end a bevel gear 110 meshing with a bevel pinion 111. Pinion 111 is journalled in projection 112 of slide 72, and is driven by a shaft 113, which is held in bearings 114, 115 of frame 70, and which can slide endwise in pinion 111. Shaft 113 receives motion from a step pulley 116. While pulley 116 moves uniformly, the pinion 80 is oscillated and in turn reciprocates table 76.

Shaft 108 carries on its right end (see Fig. 7) two cams 79, or a double acting cam, operating a forked lever 118, which is connected with tooth 78 and which controls the radial position of table 76. During the working stroke, table 76 leans with its projection 119 against guidance 120 of slide 72. To guarantee this, the member 121 which contains tooth 78 is provided with internal grooves of slight angularity, engaging external helical splines 122 of shaft 123, to whose extremity lever 118 is secured. Member 121 may move axially a slight distance, under the pressure of a spring 125, before coming to a stop 126. The proportions of the various parts are so, that during the working stroke of the blank 90 member 121 is slightly ahead of the stop 126. Spring 125 presses it against the helical splines 122 and its tooth 78 inwardly against slot 77. During the working stroke table 76 is therefore continuously pressed inwardly, towards the grinding wheels, and against guidance 120, irrespective of inaccuracies in the cams 79.

It is understood that such changes and modifications may be made in my invention as fall within the limits of the appended claims.

I claim as my invention:

1. The method of grinding gears, which consists in providing a gear blank and a grinding wheel trued to a single circular arc, in mounting said grinding wheel on an axis offset from and nonparallel to the axis of said gear blank adjacent the point of nearest approach of the axis of the grinding wheel with respect to the axis of the gear blank, the axial distance of the working surface of said grinding wheel from said point of nearest approach being smaller than the outside radius of said gear blank, in rotating said grinding wheel in engagement with a tooth side of said gear blank, and in providing angular and linear feeding motions between said grinding wheel and said gear blank.

2. The method of grinding gears, which consists in providing a gear blank and a grinding wheel trued to a single circular arc, in mounting said grinding wheel on an axis offset from and nonparallel to the axis of said gear blank adjacent the point of nearest approach of the axis of the grinding wheel with respect to the axis of the gear blank, the axial distance of the working surface of said grinding wheel from said point of nearest approach being smaller than the outside radius of said gear blank, in rotating said grinding wheel in engagement with a tooth side of said gear blank, and in providing angular and linear feeding motions between said grinding wheel and said gear blank, said feeding motions consisting of a translation along a straight line and of a rotation about the axis of the gear blank.

3. The method of grinding gears, which

consists in providing a gear blank and a pair of grinding wheels, in mounting said grinding wheels coaxially on an axis offset from and nonparallel to the axis of said gear blank, said grinding wheels being positioned on opposite sides of the point of nearest approach of the axis of the grinding wheels with respect to the axis of said gear blank, in effecting engagement between said grinding wheels and two tooth sides of different tooth spaces of said gear blank, in rotating said grinding wheels, and in providing feeding motion between said grinding wheels and said gear blank in the direction of the axis of the gear blank and angularly about said axis.

4. The method of grinding gears, which consists in providing a gear blank and a pair of grinding wheels, in mounting said grinding wheels coaxially on an axis offset from and nonparallel to the axis of said gear blank, said grinding wheels being positioned on opposite sides of the point of nearest approach of the axis of the grinding wheels with respect to the axis of said gear blank and having outwardly disposed grinding surfaces, in effecting engagement between said grinding surfaces and two tooth sides of different tooth spaces of said gear blank, in rotating said grinding wheels, and in providing feeding motion between said grinding wheels and said gear blank in the direction of the axis of the gear blank and angularly about said axis.

5. The method of grinding gears having helical teeth, which consists in providing a pair of grinding wheels, in mounting said grinding wheels adjacent a gear blank so that the axis of one grinding wheel extends in the same direction as the axis of the other grinding wheel, a grinding wheel being disposed adjacent the point of nearest approach of its axis with respect to the axis of said gear blank at a distance from said point smaller than the outside radius of the gear blank, in rotating said grinding wheels in engagement with tooth sides of different tooth spaces of said gear blank, and in providing feeding motions between said grinding wheels and said gear blank in the direction of the axis of the gear blank and angularly about said axis.

6. The method of grinding gears containing helical teeth, which consists in providing a gear blank and a grinding wheel of curved grinding profile, in mounting said grinding wheel on an axis offset from and angularly disposed to the axis of said gear blank adjacent the point of nearest approach of the axis of the grinding wheel with respect to the axis of the gear blank, the axial distance of the center of the working surface of the grinding wheel from said point of nearest approach being smaller than the outside radius of said gear blank and larger than one half of the normal circular pitch of said gear

blank, in rotating said grinding wheel in engagement with said gear blank, and in providing feeding motions between said grinding wheel and said gear blank in the direction of the axis of the gear blank and angularly about said axis.

5
7. The method of grinding gears, which consists in positioning a pair of grinding wheels with outwardly disposed grinding surfaces so as to engage opposite tooth sides of different tooth spaces of a gear blank, in rotating said grinding wheels on axes extending in the same direction, said axes being offset from the axis of the gear blank by an amount larger than the outside radius of said gear blank, and in providing feeding motion between said grinding wheels and said gear blank.

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8. The method of grinding gears, which consists in providing a pair of grinding wheels having outwardly facing grinding surfaces of curved profile, in positioning said grinding wheels so as to operate on oppositely disposed tooth sides of nonadjacent tooth spaces of a gear blank, in rotating said grinding wheels on axes offset from the axis of the gear blank by an amount larger than the outside radius of the gear blank, and in providing feeding motion between said grinding wheels and said gear blank.

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9. The method of grinding gears containing helical teeth, which consists in providing a pair of coaxial grinding wheels trued to curved profiles, in setting the axis of said grinding wheels at an angle to a plane perpendicular to the axis of a gear blank, said angle being smaller than the helix angle of the teeth at the pitch radius, in rotating said grinding wheels in engagement with opposite tooth sides of different tooth spaces of a gear blank, and in providing feeding motion between said grinding wheels and said gear blank in the direction of the axis of the gear blank and angularly about said axis.

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10. The method of grinding gears having helical teeth, which consists in providing a grinding wheel having a grinding profile of the form of a single circular arc, the radius of said arc being smaller than the radius of the grinding wheel, in rotating said grinding wheel adjacent a gear blank, and in providing feeding motions between grinding wheel and gear blank in the direction of the axis of said blank and angularly about said axis.

65
11. The method of grinding gears, which consists in providing a pair of grinding wheels having curved active surfaces trued to single circular arcs, in rotating said grinding wheels in engagement with a blank about axes extending in the same direction, in providing feeding motions between said grinding wheels and said blank.

In testimony whereof I affix my signature.
ERNEST WILDHABER.