Oct. 30, 1962 E. WILDHABER 3,060,643

THREADED ROTARY MEMBER FOR GENERATING SPUR AND HELICAL GEAR TEETH, AND METHOD AND MEANS FOR USING THE SAME

Filed May 31, 1960 3 Sheets-Sheet 1

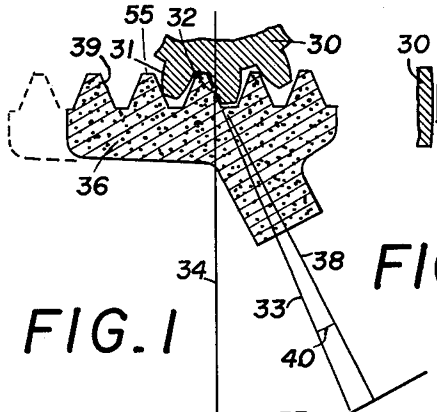

FIG. 1

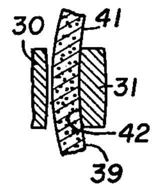

FIG. 3

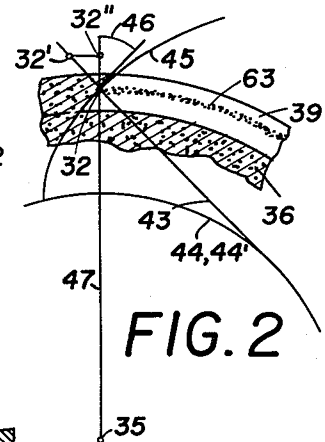

FIG. 2

FIG. 6

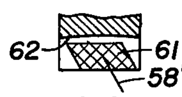

FIG. 7

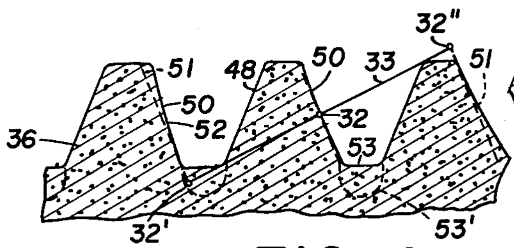

FIG. 4

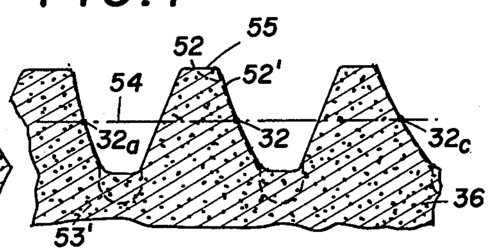

FIG. 5

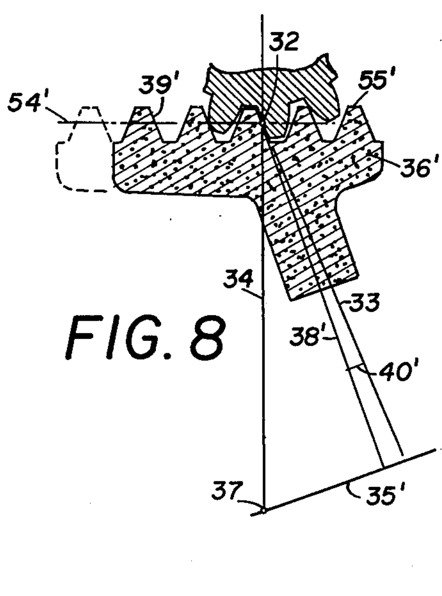

FIG. 8

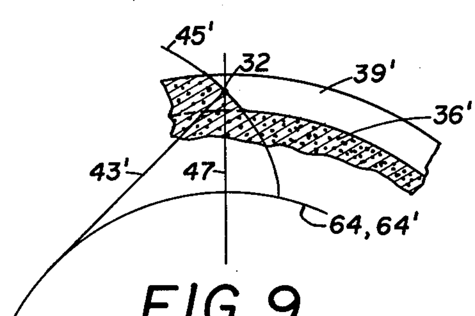

FIG. 9

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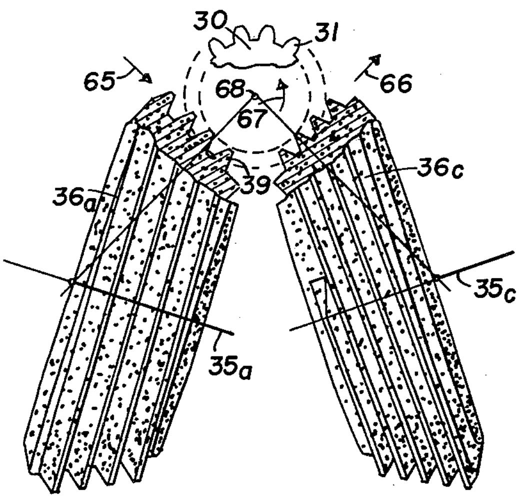

FIG. 10

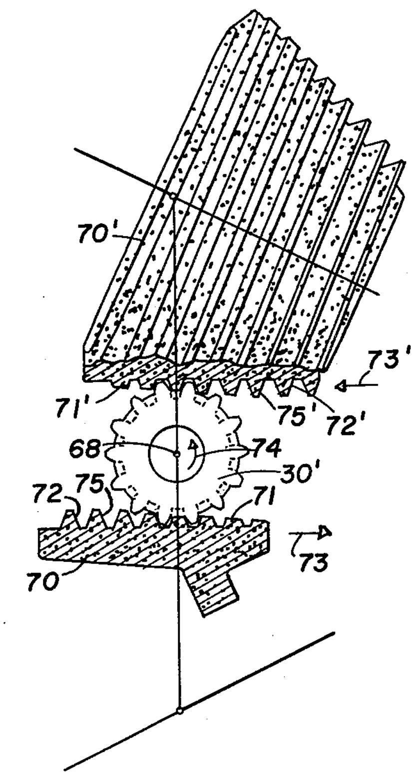

FIG. 11

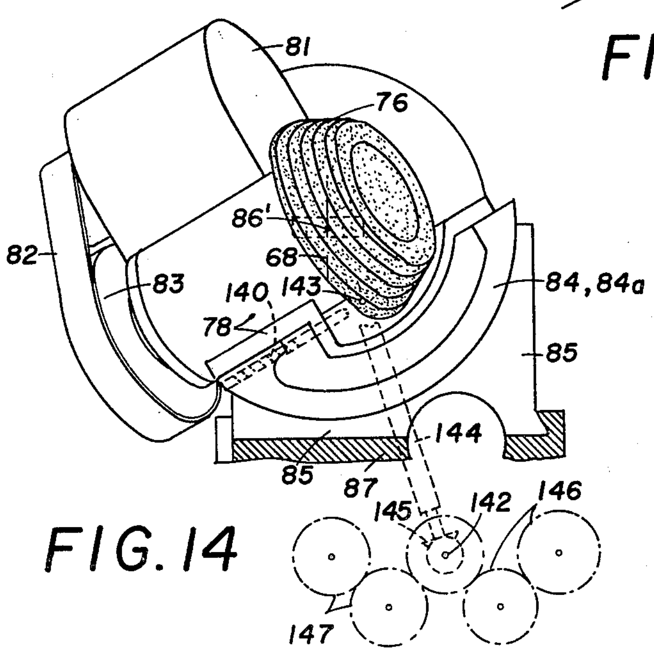

FIG. 14

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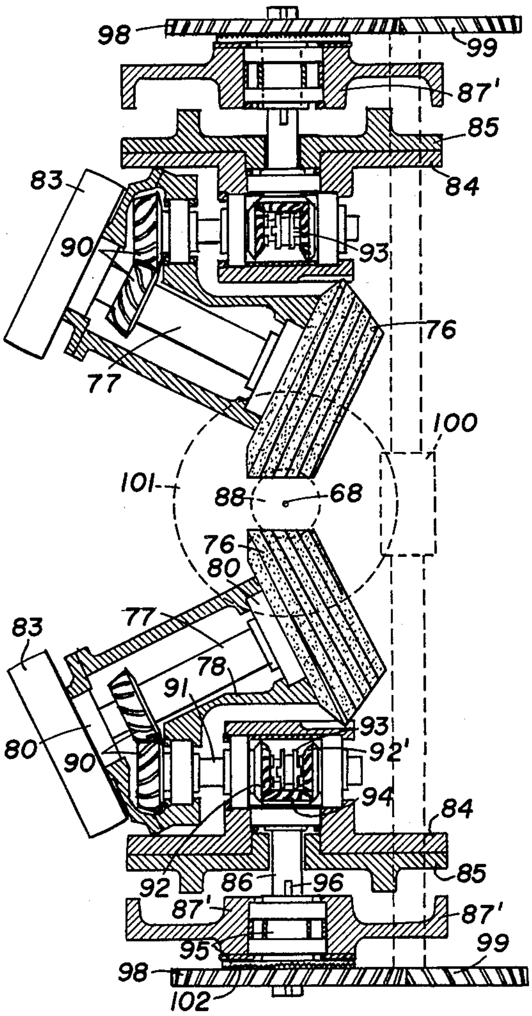

FIG. 12

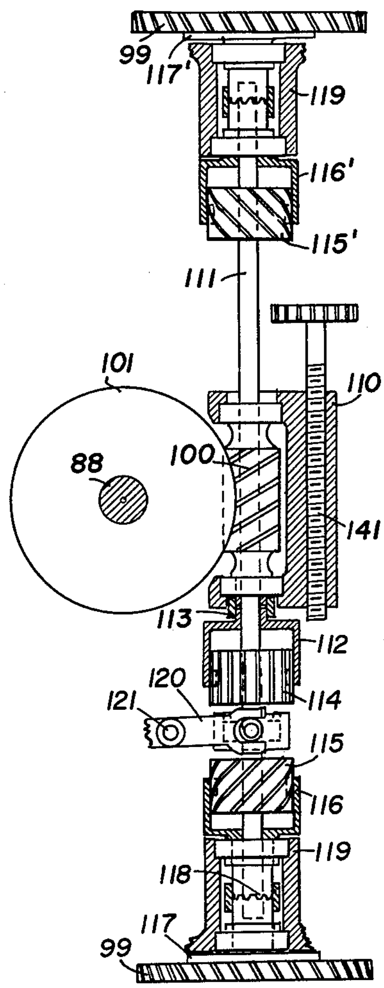

FIG. 13

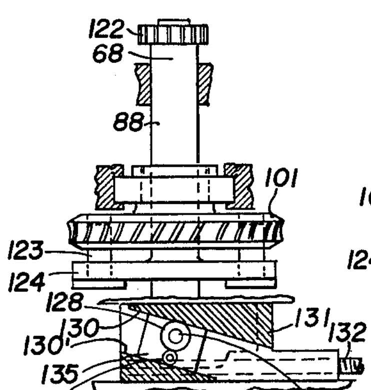

FIG. 16

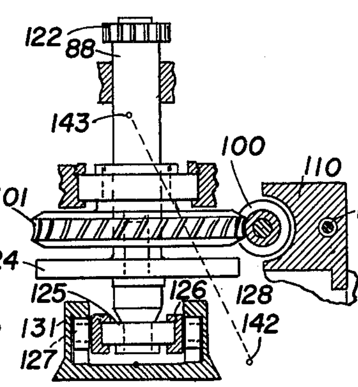

FIG. 15

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United States Patent Office

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THREADED ROTARY MEMBER FOR GENERATING SPUR AND HELICAL GEAR TEETH, AND METHOD AND MEANS FOR USING THE SAME

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Filed May 31, 1960, Ser. No. 32,872
19 Claims. (Cl. 51—89)

The present invention relates to hob-like grinding members and to a method and means for using them. More broadly it relates to hob-like rotary tool members in general.

One object of the invention is to provide a hob-like grinding or abrading member that is far more efficient than comparable known members and that has a wider working contact.

A further object is to devise a hob-like grinding or abrading member that is capable of sweeping the whole width of the gear teeth in a single bodily position, and one that has an essentially helical grinding surface.

Another aim is to devise an improved and highly efficient grinding or abrading member for generating the tooth sides of spur gears and helical gears.

A further aim is to devise a hob-like rotary member, especially a grinding or abrading member, that is capable of producing crowned teeth, having tooth surfaces eased off adjacent their ends, and that is capable of sweeping the entire width of said surfaces in a single bodily position, without feed lengthwise of the gear axis.

While my novel grinding member can be used on existing machines, a modified grinding method and a modified grinding machine is preferably used to take full advantage of this member.

It is a further object to devise such a method and the means for carrying it out.

Other objects will appear in the course of the specification and in the recital of the appended claims. These objects may be attained singly or in any combination.

In the drawings:

FIG. 1 is a normal section of a grinding member constructed according to the present invention and of gear teeth in engagement therewith. This normal section through the grinding member is almost identical with an axial section, because of the small lead angle of the generally single-threaded member.

FIG. 2 is a fragmentary section taken at right angles to the rotational axis of this member, and a diagram explanatory of its shape.

FIG. 3 is a fragmentary longitudinal section of this member, shown in engagement with gear teeth.

FIG. 4 is a fragmentary and enlarged axial section of the member shown in FIGS. 1 to 3, explanatory of the basic grinding surface that produces exact involute tooth profiles without modification.

FIG. 5 is a fragmentary and enlarged axial section similar to FIG. 4, showing how the thread shape should be altered if tooth profiles eased off adjacent their ends shall be produced.

FIG. 6 is a fragmentary axial section of a spur gear produced with a hob-like member as shown in FIGS. 1 to 3, showing the localized tooth bearing of such a gear.

FIG. 7 is a fragmentary axial section of a helical gear generated with such a member, showing the shape of the localized tooth bearing.

FIG. 8 is a normal section of a grinding member and of gear teeth in engagement therewith, generally similar to FIG. 1, but relating to a modification.

FIG. 9 is a fragmentary section taken at right angles to the rotational axis of the member shown in FIG. 8.

FIG. 10 is a view taken along the axis of a spur gear in grinding contact with a pair of grinding members constructed according to the present invention, illustrating a way of using these members. They are shown partly in axial section.

FIG. 11 is an axial view of a spur gear being generated from a solid blank, showing a preferred disposition of the pair of grinding members, and explaining the method followed.

FIG. 12 is a diagrammatic plan view and horizontal section of a gear grinding machine adapted for use of the hob-like grinding members described with FIGURES 1 to 7, with the tool spindles set to a horizontal position.

FIG. 13 is a plan view and horizontal section on the level of the index worm of this machine.

FIG. 14 is a fragmentary front elevational view corresponding to FIGS. 12 and 13, looking at a grinding member at right angles to its pitch surface and radially of the gear axis, the grinding member being set angularly to grind a helical gear.

FIG. 15 is a side view of the work support of the machine shown in FIGS. 12 to 14, looking along the axis of the index worm 100, and partly a section taken at right angles to the viewing direction.

FIG. 16 is a side view, partly a section, similar to FIG. 15 but taken in a direction looking from left to right in FIG. 12.

The drawings show the invention as applied to involute teeth. The gear 30, FIGS. 1 and 3, has teeth 31. If the gear 30 is a spur gear with straight teeth parallel to its axis, then the sectional plane is perpendicular to the gear axis. On helical gears the section is at right angles to the pitch helix, the helix of the teeth at pitch point 32. To some degree the grinding member represents a rack. Its profile tangent at pitch point 32 coincides with the rack profile shown extended at 33. 34 is the pitch vertical, the normal to the pitch surface of gear 30 at pitch point 32. It lies in the drawing plane of FIG. 1. The axis 35 of the grinding member 36 intersects the pitch vertical at 37 and includes an acute angle therewith. Axis 35 is slightly inclined to the drawing plane of FIG. 1 because of the lead angle of member 36. A plane through point 32 perpendicular to axis 35 intersects the drawing plane in a line 38 that includes a small angle 40 with the rack profile 33.

On a conventional cylindrical hob-like member the rotational axis is at right angles to the pitch vertical 34, and the said intersection line coincides with the pitch vertical 34 instead of being at 38. It should be noted that the rack profile 33 is oppositely inclined to the essentially radial line 38 than on a conventional hob-like member. It might be stated that the thread side 39 has a negative profile inclination to the radial direction of member 36. While the conventional thread side is convexly curved in a section lengthwise of the thread side, and lengthwise of the engaged tooth, it is here concavely curved. This is illustrated in FIG. 3 with exaggeration. The sectional profile 41 of the thread side is concave. It produces a tooth side 42 that is convex lengthwise, a crowned tooth side.

The section perpendicular to the rotational axis, FIG. 2, tells more about this grinding surface. Basically it is an involute helicoid, a helicoid of constant lead containing a straight line element 43. The surface normals at all points of this element are parallel and in the axial view, FIG. 2, coincide with element 43. They constitute a plane tangent to a cylindrical base surface 44. A plane perpendicular to the axis 35 of the grinding member intersects its working surface in an involute 45, shown extended in FIG. 2. It is the involute of a base circle 44′ that lies on the cylindrical base surface 44.

As angle 40 is relatively small, the radius of the cylindrical base surface 44 is relatively large, much larger than on a conventional member. **46** is the profile inclination of involute **45** to the radial direction **47**. It is also the pressure angle in this transverse section.

If angle **40** were zero, the base circle **44'** would pass through the pitch point or mean point **32**, and the profile inclination (**46**) would be zero. This would result in a very sharply curved thread surface at point **32**, and would exclude all conjugate action between member **36** and gear **30** from the pitch point **32** inwardly towards axis **35**. My invention keeps safely away from this condition by using a profile inclination **46** of at least thirty degrees to the radial direction **47**.

Because of said negative profile inclination the involute sectional profile **45** is concavely curved, and the grinding surface is slightly internal.

FIG. 4 shows an axial section of the grinding member at a larger scale. The side **48** is the clearance side that is kept out of contact with the workpiece. Numeral **50** denotes the basic grinding surface, which is an involute helicoid. The dotted lines **51** show the straight rack profile. It is tangent to the profile **52** of the helicoid at pitch point **32**, and at all points **32'**, **32''** of a line **33** drawn through point **32** parallel to the axis (**35**) of the helicoid. In this axial section the profile **52** is concavely curved, but much less so than the involute profile in planes perpendicular to its axis. A member containing this basic grinding surface is capable of producing spur gears and helical gears with exact involute profiles.

The term helical gear is used throughout in its broad sense, and includes herringbone gears and all gears with helical teeth. Also while the thread bottom **53** is shown straight, it should be understood that other thread bottoms may be used if desired, such as the recessed bottom shown in dotted lines **53'**. While grinding members are specifically referred to, the invention applies broadly to tool members having working portions disposed in the described thread surfaces.

In general slight modifications from the mathematically exact and conjugate shape of the teeth are desired, so that the tooth surfaces are eased off adjacent all their boundaries. The described involute helical grinding surface produces surfaces eased off adjacent the longitudinal ends of the teeth. Profile-wise ease-off is attained by curving the concave profiles **52'**, FIG. 5, more than the profiles **52** of the basic helicoid. The latter profiles are shown in dotted lines in FIG. 5, while being shown in full lines in FIG. 4. The profiles **52'** are tangent to the profiles **52** at the points (**32***a*, **32**, **32***c*) of a pitch line **54** which approximately follows the tapered outside surface **55** of the grinding member.

While the conventional hob-like grinding members for grinding spur gears and helical gears are fed relatively to the gear being generated in the direction of the gear axis, to gradually envelope the entire length of the tooth surfaces, member **36** sweeps the entire surfaces of one side of the teeth in a single bodily position. No axial feed is required. This gives a much faster grinding operation than has hitherto been possible. At the same time a desired ease-off may be accomplished.

A preferred way of finish grinding comprises setting the grinding member and the gear to be ground to the required bodily position, without contacting each other, and then changing the rotational timing between the gear and member to approach them into contact and to a final timing position. In this final position the entire tooth surfaces are completely swept and finished.

FIG. 6 illustrates a tooth bearing **56** attainable on a spur gear **57** when no profile-wise ease-off is provided. The tooth bearing follows the projected mean tooth surface normal (**58**) in this peripheral view. Heavy load is kept away from the tooth ends **60** even when the gears are inaccurately mounted. When profile-wise ease-off is added the tooth bearing area swept in a fixed bodily position under light load becomes oval, as known.

FIG. 7 illustrates a tooth bearing **61** attainable on a helical gear, without profile ease-off. Again it follows the projected mean tooth surface normal (**58'**), as it appears in this peripheral view taken at right angles to the gear axis.

In both cases, FIG. 6 and FIG. 7, the tooth bottom **62** is slightly concave. By increasing the diameter of the grinding member gears of increased face width can be ground while keeping the concavity of the tooth bottom within acceptable limits. Nevertheless there is a limit to face width beyond which it becomes less practical to use the described member **36**.

For a larger face width the conventional feed along the gear axis is preferably retained, and a modified grinding member **36'** is used. It will now be described with FIGS. 8 and 9.

Member **36'** is generally similar to member **36**. It has a tapered outside surface **55'**. Its axis **35'** intersects the pitch vertical **34** at point **37** and is slightly inclined to the drawing plane of FIG. 8. A plane laid through pitch point **32** at right angles to axis **35'** intersects the drawing plane in a line **38'** that includes a small angle **40'** with the rack profile **33**. Angle **40'** is opposite to angle **40** of FIG. 1, line **38'** being drawn from point **32** to the same side of rack profile **33** as the pitch vertical **34**. As a result the thread side **39'** is convexly curved in a longitudinal section, as is the thread side of a conventional hob-like grinding member, but less so. It is oppositely curved as compared with thread side **39**, FIG. 3. The lengthwise curvature is about proportional to the angle **40'**, which compares with the inclination angle of the rack profile **33** to pitch vertical **34** on a conventional member. The contact between the grinding member and the gear **30** is over a much wider zone, so that the grinding efficiency is very materially increased.

FIG. 9 shows a section taken at right angles to the rotational axis **35'** of member **36'**. The straight-line element **43'** of the involute helicoid is oppositely inclined to the radial direction **47** as compared with line **43** of FIG. 2, even though both members **36**, **36'** have the same hand.

The tooth surface normals at all points of elements **43'** are parallel and lie in a plane appearing as line **43'** in FIG. 9. It is tangent to the cylindrical base surface **64** of the involute helicoid. The drawing plane intersects the grinding surface **39'** in a convex involute **45'** with base circle **64'**. Conventional feed along the gear axis is used, with a relative turning motion added on helical gears, and a faster feed rate.

Profile modification can be provided on member **36'** in the way described with FIG. 5. Ease-off lengthwise of the teeth may be obtained in any suitable known way.

The Method

Both members **36** and **36'** and conventional hob-like grinding members share the characteristic that the grinding contact does not by itself sweep the whole extent of the grinding surface. The working contact extends in a spiral ribbon **63** (FIG. 2) between the top and bottom of the thread side. Other portions of the thread side can be brought into grinding contact by resetting the grinding member.

According to the invention the grinding member is displaced along a straight line inclined to the direction of its axis (**35'**, **35'**) and following the outside surface (**55**, **55'**) in the mesh region. It is ordinarily displaced in the direction of the pitch line, (**54**, FIG. 5). The timing between the member (**36**, **36'**) and the workpiece is changed in accordance with the linear displacement. A further change is required, especially with member **36**. The combined changes move for instance point **32'** of element **43** (or **43'**) to the pitch point **32**. The linear displacement **32'**—**32** is made up of a displacement **32''**—**32** in an axial plane of the member and of a lateral displacement **32'**—**32''**. The lateral displacement is preferably imparted to the workpiece and comprises an axial displacement thereof.

When on a machine a grinding member of given pitch is to be used exclusively, a special slide construction may be provided to attain displacement 32′—32 directly, without splitting it into components.

Shifts of the grinding member may be made from time to time, after grinding one or more workpieces, or continuously if desired. Through such shifts the grinding contact is spread over a large portion of the grinding surface and uneven wear is avoided.

In a modified method the displacement component 32′—32″ is replaced by a change in the hob-setting angle. The hob is preferably set for lead angle about an axis coinciding with the pitch vertical 34.

One form of a general arrangement will now be described with FIG. 10. A pair of members 36*a*, 36*c*, with axes 35*a*, 35*c* are rotatably mounted for engagement with opposite sides respectively of the teeth 31 of a gear 30, so that the axes 35*a*, 35*c* include a fixed angle with each other. The two members 36*a*, 36*c* are identical, and each has a grinding surface 39 inclined at but a small angle to the radial direction of the member.

To move the grinding contact on said members, member 36*a* may be displaced in the direction of arrow 65 and member 36*c* equally in the direction of arrow 66, so that the accompanying timing change can be imparted to the gear 30. The gear 30 is then turned in the direction of arrow 67 through the same number or fractional number of pitches as the linear displacement of the members contains.

In a modified procedure the two members 36*a*, 36*c* are shifted towards each other, one member being shifted in the direction of arrow 65 while the other member is shifted in a direction opposite to arrow 66. Instead of a timing change along arrow 67 an individual and opposite timing change is made on the two members.

In both procedures an additional displacement is made. In the one first described it is preferably imparted to the gear and comprises a displacement along the gear axis.

The various setting changes are preferably made simultaneously, as will be further described in connection with machine structure.

The members 36*a*, 36*c* as shown are of the type of member 36 (FIGS. 1 to 7). They could also be of the type of member 36′ (FIGS. 8 and 9). In the latter case feed lengthwise of the gear axis (68) should be added, and on helical gears also a timing change proportional to the feed. In both cases the members have their working portions facing the small end of their taper.

FIG. 11 illustrates a further embodiment using a grinding member of the type of member 36. This modification is for grinding teeth from a solid blank rather than from a blank whose teeth have been precut. A pair of members 70, 70′ are used that contain roughing portions and finishing portions. The roughing portions 71, 71′, are provided on thread parts of gradually increasing depth, while the finishing portions 72, 72′ are on the full-depth thread parts. The members 70, 70′ have outside surfaces of composite taper, and engage opposite sides of the teeth of a gear blank 30′ with axis 68. Tapered member 70 has its roughing portions 71 disposed adjacent its small end, while member 70′ has its roughing portions 71′ disposed adjacent its large end. Each member 70, 70′ is fed in its axial plane in the direction of arrows 73, 73′ respectively, while the workpiece 30′ is turned on its aixs 68 in the direction of arrow 74 as if meshing with the members 70, 70′. More roll may be used for finishing than is needed for generating the full shape, to reduce wear on the grinding members by spreading it out. The roughing and the finishing portions lie on the same thread surface (75, 75′) without break. Preferably the timing of the two members 70, 70′ is slightly changed in opposite direction between roughing and finishing, to remove a suitable small amount of stock in finishing.

An additional displacement is used at least during finishing. It is preferably imparted to the gear and is an axial displacement thereof, plus a change of timing on helical gears.

In the procedure described with FIG. 11 the stock removal is mainly with the thread tops of the roughing portions 71, 71′ while the finishing portions are preserved for finishing.

Identical grinding members may be used when one member (70) is fed in a direction opposite to arrow 73, while member 70′ is fed along arrow 73′. The members are then both like member 70′. The timing should then be oppositely changed on the two members, and the said additional displacement is imparted individually to the two members to combine with the other named bodily motion thereof.

Machine Structure

While the novel grinding members or tool members can be used on existing machines, such use puts them at a disadvantage. A machine for their use should have special features which are now to be described.

Each member is mounted on a slide movable in a direction at an angle to its axis, approximately along the pitch line of the member, or in a direction tangential to its pitch surface and to the outside surface of the finishing parts. A pair of members is used, acting on opposite tooth sides of a workpiece. The means for moving their said slides are operatively connected, so that the slides are moved simultaneously. Also connected with said means are means for changing the timing between the members and the workpiece. An additional displacement or displacement component is provided that may include an axial displacement of the workpiece. The means for effecting this additional displacement are preferably also operatively connected with the other named means, so that all these displacements are made simultaneously, after unclamping the slides and other movable parts participating in these displacements.

Provision is made to set each member about an adjustment axis so that its position conforms with its lead angle and the tooth helix angle when the teeth are helical. This adjustment axis preferably intersects the rotational axis of the respective member at an acute angle. It is perpendicular to the motion of the aforesaid slides.

The machine illustrated is for use of a pair of tapered grinding members of the type of member 36. Each member 76 is secured to a spindle 77 (FIG. 12) rotatably mounted on a slide 78 that is movable along the pitch line of the respective tapered member, at an acute angle to the rotational axis of spindle 77. It is journalled in antifriction bearings 80 and is driven from a motor 81 (FIG. 14) with a belt 82 acting on pulley 83. Slide 78 is carried by a swivel head 84 adjustable about a horizontal axis. This axis 86′ intersects the axis 68 of the work support at right angles. It coincides with the axis of shaft 86 and with the pitch vertical (34, FIG. 1). The swivel head 84 rests on a base slide 85 that is adjustable on the base or frame 87 of the machine towards and away from the work support 88. It has a cradle-like arcuate projection 84*a* (FIG. 14) that bears on slide 85 directly underneath the weight of the parts carried.

The machine illustrated uses mechanical timing between the work support and the tool support (77). A pair of angular bevel gears 90 transmit motion between the tool spindle 77 and a shaft 91 that extends in the direction of motion of slide 78. A pair of opposite miter gears 92, 92′ are rotatably mounted on swivel head 84 coaxially with shaft 91 and in an axially fixed position. A shift clutch 93 permits to connect them selectively with shaft 91, to transmit motion to a mating miter gear 94. The latter is also rotatably mounted in an axially fixed position on swivel head 84. It is rigid with shaft 86. At its opposite end shaft 86 engages the hub of a head 95 with a sliding key 96. Head 95 is rotatably mounted in an axially fixed position on a projection 87' rigid with the machine frame 87. On its outer end head 95 contains teeth forming one member of a toothed face coupling 102. A gear 98 with mating coupling teeth is secured to head 95 coaxially therewith. It meshes with another gear 99 that is coaxial with a worm 100. Worm 100 meshes with a wormgear 101 and drives the work support.

This description applies to each of the two tool spindles.

In an endeaver to point out the novel features rather than describe the state of the art I have simplified the drawings and description, leaving out such obvious features as screws and other clamping means, adjustment means except where new, guards, safety and lubrication features, automatic operation features, etc. Such means and features may of course be used where desired.

Each grinding member 76 is set to the desired angular position by adjusting the swivel head 84 on base slide 85.

Adjustment of slide 78 spreads the wheel wear, as described. It causes the shaft 91 to slide axially with respect to miter gears 92, 92' and to clutch 93, to which it is slidably keyed. Adjustment of the base slides 85 permits to adapt the position of the grinding members to the diameter of the gear blank and is further desired for loading unloading. Face coupling 102 permits of individual fine adjustment of the turning position of the tool spindles with respect to the work support 88.

The gears 98, 99 are changed for different tooth numbers of the workpiece. On machines for small production lots preferably compound change gears are used instead of the pair 98, 99. The gear ratio should be such that the overall turning ratio between each tool spindle and the work spindle equals the ratio of the number of teeth in the gear to the number of threads in the grinding member. Usually single threads are provided thereon.

The drive between the gears 99 and worm 100 will now be described with FIG. 13. The worm 100 is rotatably mounted on a slide 100 that is movable in the direction of the worm axis. It is constrained to turn with a shaft 111 coaxial with worm 100 and passing through a central bore thereof: An internal gear 112 is rigidly connected with worm 100 by a toothed face coupling maintained in engagement under pressure by a sleeve 113 with internal threads of opposite hand. The internal gear 112 engages an external spur gear 114 rigidly secured to shaft 111. The relatively large diameter of gear 114 keeps the tooth loads low and permits easy axial sliding between the worm and shaft 111.

A pair of further gears 115, 115' are also rigidly secured to shaft 111. They contain helical teeth of opposite hand, and engage mating internal gears 116, 116' respectively. These are rigidly secured to heads 117, 117' respectively by means of toothed face couplings 118. Each head 117, 117' is rotatably mounted in an axially fixed position on a portion 119 rigid with the machine frame 87. It contains a flange to which gear 99 is secured.

The shaft 111 is movable axially by means of a lever 120 pivoted at 121 on the machine frame, or by any other suitable means. The lever 120 may be cam-operated or manually operated if desired.

The axial displacement of shaft 111 adds an opposite turning motion to the two tool spindles, so that the working surfaces of the two grinding members can be moved towards the opposite tooth sides engaged thereby, without change of their bodily position. They continue to remove stock until the axial displacement of shaft 111 is brought to a stop. In this position the entire final tooth surfaces are swept by the grinding members.

Shift of Grinding Members

The workpiece 122 (FIGS. 15, 16) is secured to the work support or work spindle 88 that turns with wormgear 101, but is axially movable while the wormgear 101 is mounted in an axially fixed position. The drive is through a pair of cylindrical pins 123 projecting axially from a disk 124 rigid with the work spindle. The pins 123 reach into bores provided on the wormgear.

The axial position of spindle 88 is changed whenever the slides 78 are shifted to prevent localized wear of the grinding members. The lower end of the work spindle carries a thrust bearing 125 held by a ring 126 that has a pair of coaxial pins 127 projecting radially therefrom. If desired, guide means may be added for constraining the ring 126 to move in the direction of the axis of the work spindle. The pins 127 mount rollers 128. These engage sloped sides 130 provided on a slide 131 whose position is controlled by a screw 132. A resilient roller 133 contacts the sides 130' opposite and parallel to sides 130, to avoid backlash by causing pressure on both sides 130, 130' and between the rollers 128, 133. A cage 135 keeps roller 133 in position. It slides along the slot between the parallel sides 130, 130'.

Each slide 78 is adjustable or movable by means of a screw 140 diagrammaticaly indicated in FIG. 14. As described with FIGS. 10 and 11 such slide displacement requires a timing change here imparted to the work spindle. It is effected by displacing worm slide 110. According to the invention the screw 140 and the screw 141 that displaces slide 110 are operatively connected, so that both screws are simultaneously operated. The screws 140 that move the two slides 78 of the grinding members are interconnected for simultaneous displacement of said slides in opposite directions, as in directions 73, 73' shown in FIG. 11. They are both connected with a shaft 142 diagrammatically indicated by its axis in FIG. 14. The connection is by a known bevel gear arrangement (not shown) with apex 143, that permits the angular settings of the grinding members, by a telescoping shaft 144 and a pair of miter gears 145. The telescoping shaft and said miter pair are constrained to move lengthwise of shaft 142 together with base slide 85 upon adjustment of the latter. Shaft 142 is mounted on the machine frame. It drives screw 141 by means of change gears 146 indicated by their pitch circles. It drives the screw 132 by means of change gears 147. Accordingly the ratio between the timing change operated by screw 141 and the slide movement operated by screws 140 can be changed at will. Also the ratio between the axial displacement of the work spindle and the slide movement can be changed at will. Furthermore the change is simultaneous. The slide adjustment and related changes may be operated by hand or mechanically, as by a cam.

The described structure is not confined to a grinder, but applies broadly to machines using the described tool members.

The invention is capable of further embodiments, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principle of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth and as fall within the scope of the invention or the limits of the appended claims.

I claim:

1. A threaded rotary member with tapered outside surface, for generating one side of spur and helical gear teeth, having working portions disposed in a thread side inclined to the peripheral direction and facing the small end of said tapered outside surface, the means profile inclination of an axial section of said thread side being less than twelve degrees to the direction radial of the axis of said member but differing from zero enough that the mean profile inclination in a section perpendicular to said axis is at least thirty degrees to the radial direction.

2. A threaded rotary member for generating one side of spur and helical gear teeth, having working portions

disposed in an approximately helical thread side coaxial with the rotational axis of said member, said thread side having a negative profile inclination with respect to the radial direction of said member, so that said thread side is concavely curved in a section lengthwise of said thread.

3. A threaded rotary member according to claim 2, that has a tapered outside surface, and wherein said thread side is an involute helicoid, at least approximately, whose negative profile inclination to the radial direction is less than twelve degrees.

4. A threaded rotary member according to claim 1, whose working side is basically an involute helicoid containing straightline elements tangent to a cylindrical base surface.

5. A threaded rotary member according to claim 4, where the basic involute helicoid of the working side is modified to produce relief at the profile ends of the teeth, so that the profiles of an axial section of said side are concavely curved and tangent to the profiles of the basic involute helicoid at points of a line that approximately follows the tapered outside surface of said member.

6. A threaded rotary grinding member with tapered outside surface for generating one side of spur and helical gear teeth, having an approximately helical working side, said side having a negative profile inclination with respect to the direction radial of the axis of said member, so that said side is concavely curved lengthwise, the outside surface of said member having a composite taper, the thread that contains said working side following one taper and changing in depth on the remaining part of said composite taper while the width of the thread at the outside increases with decreasing thread depth.

7. The method of generating one side of spur and helical gear teeth, which comprises providing a threaded rotary tool member having working portions disposed in an approximately helical thread side that is concavely curved lengthwise, rotating said tool member on its axis in engagement with a gear to be produced while rotating said gear on its own axis in time with said tool member, to sweep the entire side surface of each engaged tooth in a single bodily position of said tool member and of said gear, without feed lengthwise of the gear teeth.

8. The method of grinding the side surfaces of spur and helical gear teeth, which comprises providing a pair of threaded rotary grinding members having tapered outside surfaces, each of said members having a working surface that is approximately helical and that is concavely curved lengthwise, engaging the working surface of said members with opposite sides of the teeth of a gear to be ground, rotating said members and said gear on their respective axes in time with each other, and relatively advancing the working surfaces of said members towards the engaged tooth sides by changing the timing between said grinding members and said gear and without changing their bodily positions, so as to sweep the entire tooth sides in a fixed bodily position of said members and gear.

9. The method of generating one side of spur and helical gear teeth, which comprises providing a threaded rotary tool member having a tapered outside surface and having working portions disposed in an approximately helical surface, rotating said tool member on its axis in engagement with a gear to be produced while rotating said gear on its own axis in time with said tool member, effecting feed motion between said tool member and gear, and avoiding localized tool wear by displacing said tool member relatively to said gear in a straight path inclined to the axis of said tool member, while simultaneously changing the timing between said tool member and gear in accordance with said displacement.

10. The method according to claim 9, wherein the relative displacement of said tool member to avoid localized tool wear is in a plane containing the axis of the tool member and the pitch vertical of the gear, and wherein an additional relative displacement between said tool member and gear is effected to preserve the general position of contact between said member and gear.

11. The method of grinding spur gears and helical gears from solid blanks, which comprises providing a pair of threaded rotary grinding members having outside surfaces of composite taper, each of said grinding members having a thread following one taper and changing in depth on the remaining part of said composite taper, so as to have a thread width at the outside increasing with decreasing thread depth, the working surface of each member being concavely curved lengthwise and lying in a helical surface at least approximately, engaging the low-depth portion of the working surface of said members with opposite sides of the teeth to be generated on a gear blank, and effecting feed motion between said members and blank to gradually move the full-depth portion of said thread into grinding engagement.

12. In a machine for producing spur and helical gear teeth, a rotary work support, a rotary tool support for mounting a tapered hob-like tool, means for rotating said supports in timed relation, a slide whereon said tool support is mounted with its rotational axis at a fixed acute angle to the direction of motion of said slide, means for displacing said slide in a straight path in a direction at an angle to the axis of said work support for spreading tooth contact over further working portions of said tool, and means for changing the rotational timing between said supports in accordance with the displacement of said slide.

13. The combination according to claim 12, wherein the last-named two means are operatively connected for simultaneous operation.

14. In a machine for producing spur and helical gear teeth, a rotary work support, a rotary tool support for mounting a tapered hob-like tool, means for rotating said supports in timed relation, a slide whereon said tool support is mounted with its rotational axis at a fixed acute angle to the direction of motion of said slide, a swivel head on which said slide is movable in a straight path in a direction at an angle to the axis of said work support for spreading tooth contact over further working portions of said tool, the axis of said swivel head intersecting the rotational axis of said tool support at an acute angle and being perpendicular to the direction of motion of said slide, means for displacing said slide, and means for changing the rotational timing between said supports in accordance with the displacement of said slide.

15. In a machine for producing spur and helical gear teeth, a rotary work support, a rotary tool support for mounting a tapered hob-like tool, means for rotating said supports in timed relation, a slide whereon said tool support is mounted with its rotational axis at a fixed acute angle to the direction of motion of said slide, means for displacing said slide in a straight path, means for changing the rotational timing between said supports, and means for effecting an additional position change between said supports, the last-named three means being operatively interconnected for simultaneous operation.

16. The combination according to claim 15, wherein said additional change comprises a displacement of the work support along its axis.

17. A machine for grinding spur and helical gear teeth with a tapered hob-like grinding member, comprising a frame, a rotary work support, a pair of rotary tool supports, each of said tool supports being mounted on a slide with its rotational axis at a fixed acute angle to the direction of motion of said slide, means for displacing each of said slides in a straight path in a direction at an angle to the axis of said work support for spreading tooth contact over further working portions of said tool, means for rotating said work support and tool supports in timed relation, and means for changing the rotational timing between said work support and the two tool supports equally in opposite directions.

18. A machine according to claim 17, wherein the

means for changing the rotational timing between the work support and the two tool supports equally in opposite directions comprises a shaft operatively connected with the work support, a pair of helical guide members of opposite hand rigid with said shaft, a pair of counterpart helical members engaging the first-named helical members, said counterpart members being operatively connected with the two tool supports respectively, and means for displacing said shaft axially relatively to said counterpart members.

19. A machine according to claim 17, wherein the work

support is rotated by a wormgear pair with helical worm, and wherein means are provided for moving said worm axially.

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