May 8, 1928. 1,668,932

A. AEPPLI

GEAR TOOTH GRINDING MACHINE

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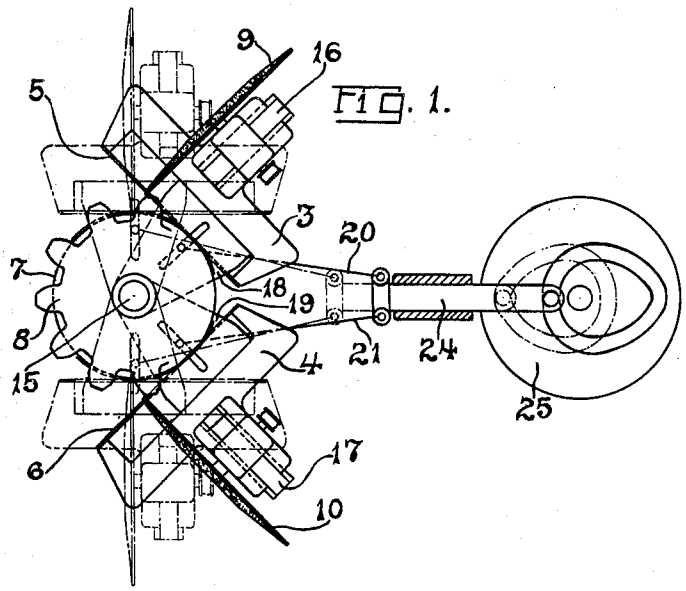


Fig. 1.

Fig. 8.

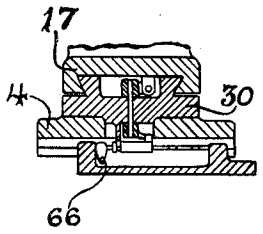


Fig. 7.

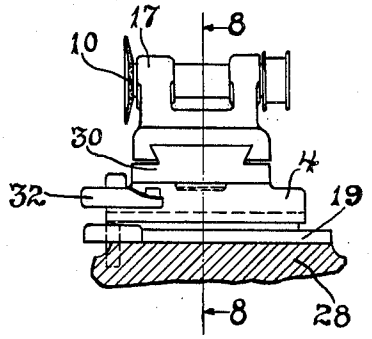
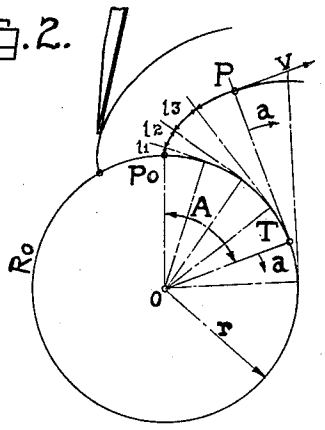


Fig. 2.



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Fig. 3.

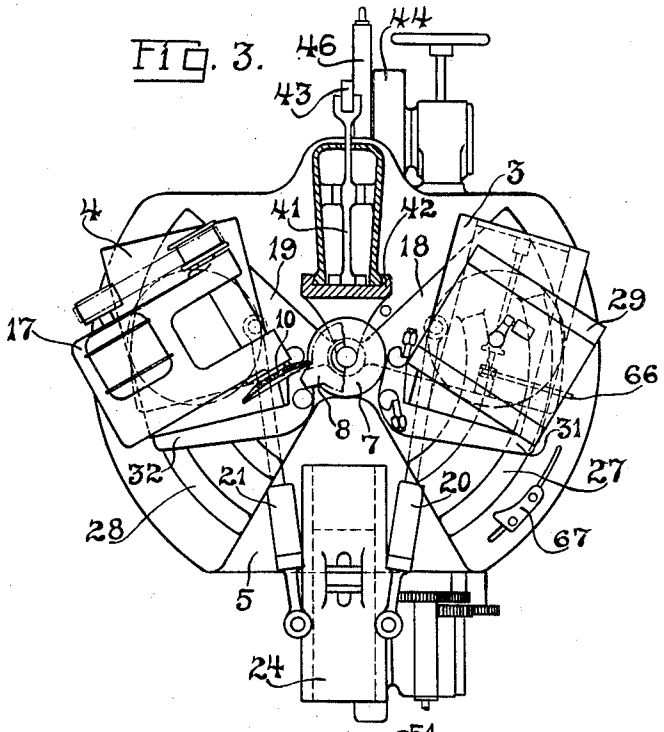
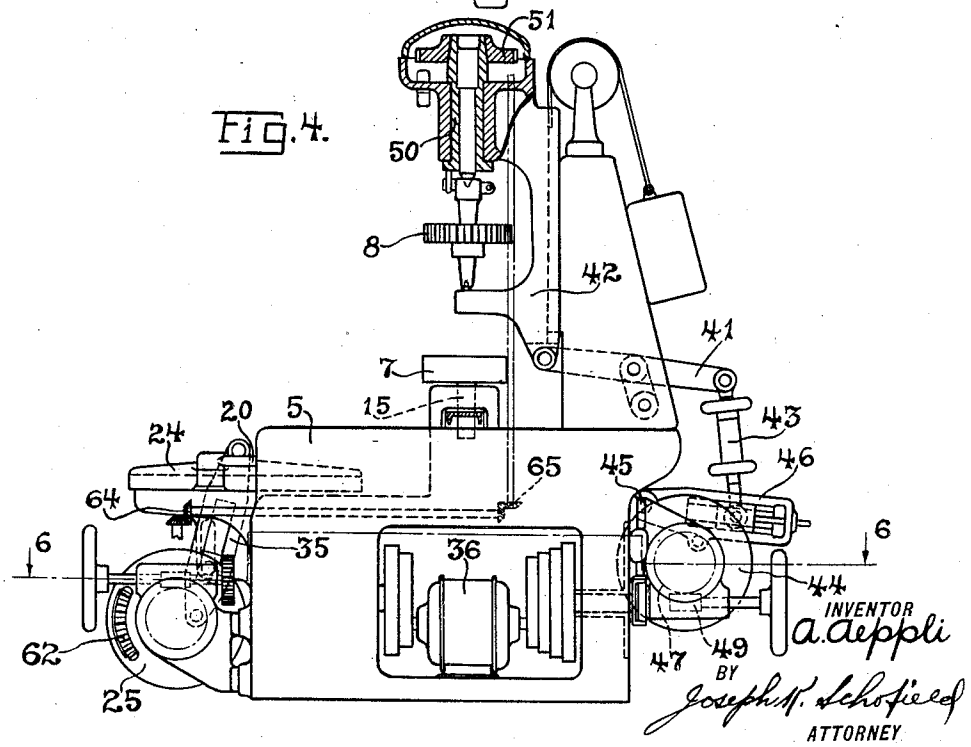


Fig. 4.



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Fig. 5.

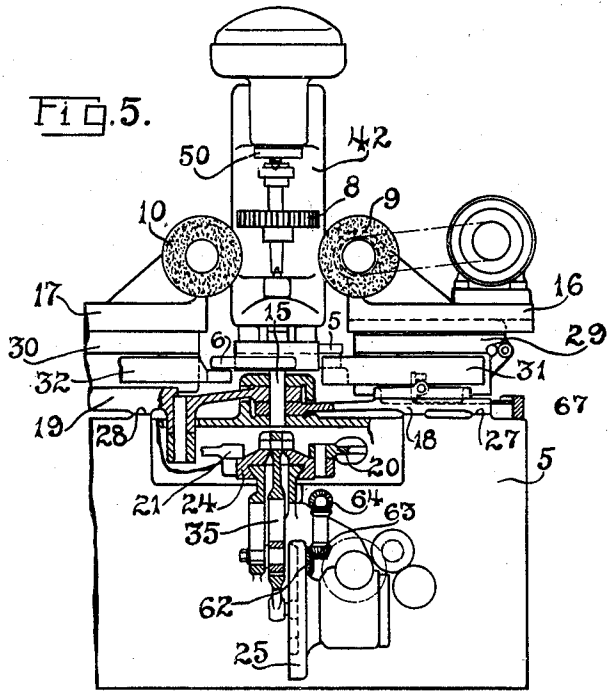
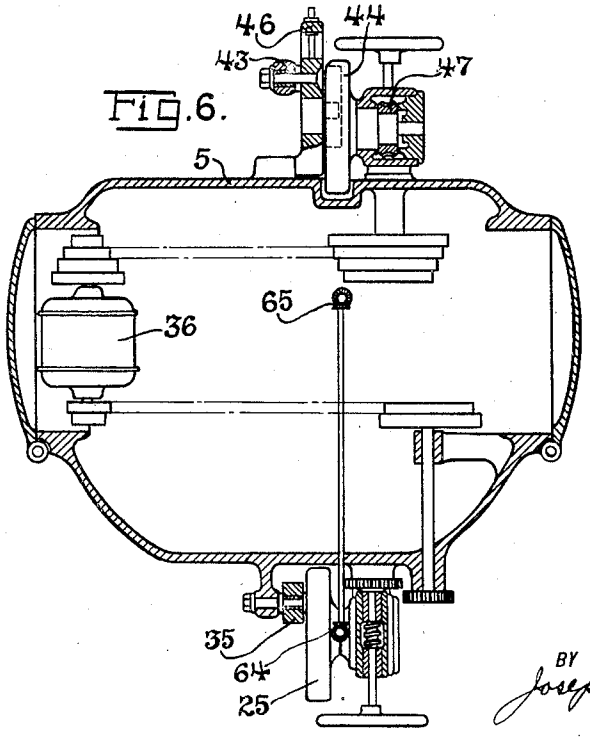


Fig. 6.



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GEAR TOOTH GRINDING MACHINE

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Fig. 10.

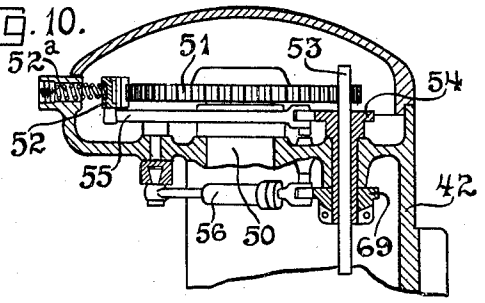


Fig. 9.

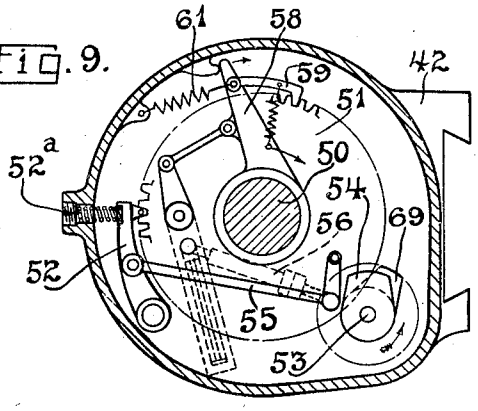
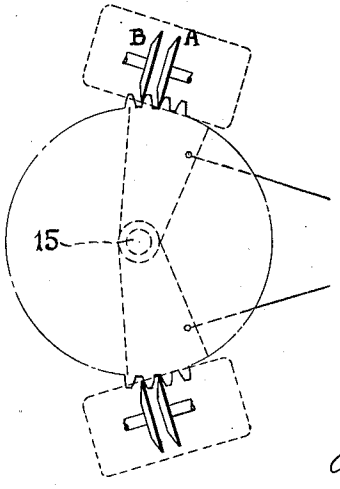


Fig. 11.



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Fig. 12.

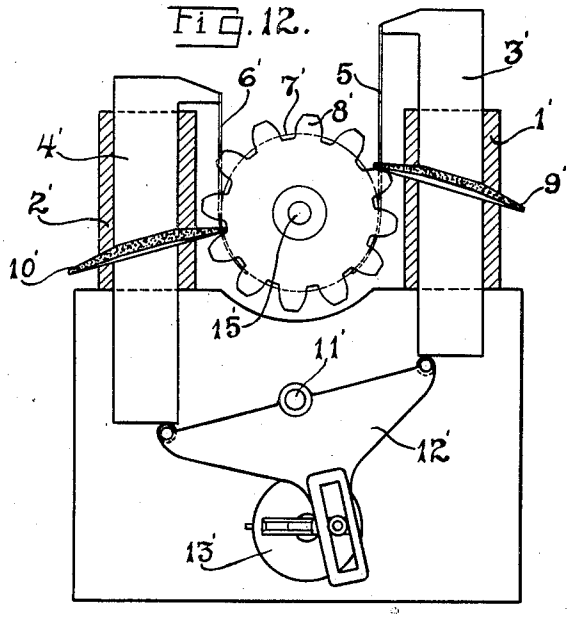
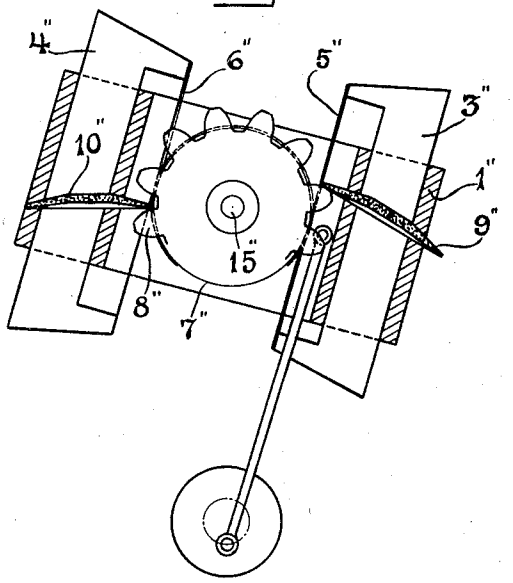


Fig. 13.



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UNITED STATES PATENT OFFICE.

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GEAR-TOOTH-GRINDING MACHINE.

Application filed December 8, 1925, Serial No. 74,022, and in Germany February 6, 1925.

This invention relates to a machine for grinding the profiles of gear teeth, and in particular to a machine for grinding spur gear teeth of involute form.

A principal object of the invention is to provide a machine for grinding involute forms of gear teeth in which the grinding action upon opposite sides of two teeth is carried on simultaneously.

Another object of the invention is to provide a machine in which two abrasive wheels will first simultaneously engage similar portions of opposite sides of two teeth and have their griding action progress along the profile of the teeth in the same direction.

A further object of the invention is to provide feeding means for advancing the tooth engaging surface of the abrasive wheels along the profile of the teeth in a manner which will permit the wheels to continue their grinding action for a longer period on certain portions of the teeth than on other portions, or which will permit the progress of the grinding action along the tooth profiles to be controlled and varied.

Another object of the invention is to provide a gear tooth grinding machine which is adapted to operate upon a tooth profile generating principle and which has the relative motion between the wheels and the blank reduced to a minimum.

In previous forms of gear tooth grinding machines in which a relative rolling action takes place between the wheels and the gear blank the grinding action of the wheels is not exactly simultaneous. One wheel begins its grinding action before the other. The second wheels does not finish its grinding action until a period of time after the first wheel has finished its operation. This necessarily prolongs the amount of time occupied by the rolling generating motion. It is therefore a primary object of the invention to provide a machine in which the rolling motion can be reduced materially with a corresponding economy of time and increased production. Also, in previous gear tooth grinding machines acting upon the generating system the rolling motion of the blank takes place at uniform velocity while the wheels engage the blank. The progress of the grinding action along the tooth profile therefore could not be controlled.

One feature of importance is that cam means are provided for effecting the relative rolling action between the wheels and the gear blank to effect the generating movements so that the action of the abrasive surface of the wheels can be varied as desired to render the action uniform throughout the tooth profile or concentrated upon certain portions.

Another feature which is advantageous is that two wheel carrying supports are provided symmetrically disposed and simultaneously movable to advance the abrasive wheels along the tooth contours being ground.

With these and other objects in view, my invention consists in the features of construction and operation set forth in the following specification and illustrated in the accompanying drawings.

In the accompanying drawings annexed hereto and forming a part of this specification, I have shown my invention embodied in machines for grinding spur gears but it will be understood that the invention can be otherwise embodied and that the drawings are not to be construed as defining or limiting the scope of the invention, the claims appended to this specification being relied upon for that purpose.

In the drawings:

Figure 1 illustrates one embodiment of the invention shown diagrammatically in plan, the wheels and mountings therefor being shown in two operative positions.

Fig. 2 is a diagram showing the relationship between the movement of the wheel mounting and the point of contact of the wheel on the tooth profile.

Fig. 3 is a plan view of a gear grinding machine made in accordance to the diagrammatic view shown in Fig. 3.

Fig. 4 is a side elevation of the machine shown in Fig. 3, the wheel mountings being omitted.

Fig. 5 is a front elevation of the complete machine.

Fig. 6 is a horizontal sectional view through the base of the machine shown in Fig. 5 and taken on line 6—6 of Fig. 4.

Fig. 7 is a detail view of one of the wheel mountings shown in elevation.

Fig. 8 is a sectional view of one of the wheel mountings taken on line 8—8 of Fig. 7.

Fig. 9 is a horizontal sectional view of the mechanism for indexing the work carrying spindle.

Fig. 10 is a vertical sectional view of the spindle indexing mechanism.

Fig. 11 is a diagrammatic view of a grinding machine having a plurality of wheels on its wheel mountings.

Fig. 12 is a diagrammatic outline, in plan, of a modified form of the machine, and

Fig. 13 is a similar view of a still further form of the machine.

In the above mentioned drawings I have shown several embodiments of the invention which are now deemed preferable, and it is to be understood that changes and modifications may be made within the scope of the appended claims without departing from the spirit of the invention.

Briefly, and in its broadest aspect, my invention comprises the following principal parts: First, a base; second, a blank carrying spindle adapted to be indexed to present successive teeth to the wheels; third, wheel mountings, preferably adapted to be oscillated, on which are disposed suitable abrasive wheels; fourth, means for effecting relative motion between the blank spindle and the abrasive surface of the wheels to generate involute gear teeth; and fifth, means to withdraw the wheels from the gear being ground during the indexing operation.

Referring more in detail to the figures of the drawings, and first to Figs. 3 et seq., a preferred embodiment of the invention is disclosed adapted to grind two tooth profiles simultaneously and also to grind simultaneously symmetrical portions of the tooth profiles. In other words, the two wheels simultaneously engage the faces of teeth, progress in unison along the profile and finally simultaneously engage the flanks or roots of the teeth. This, as will be defined later, permits a more accurate grinding of the involute profiles.

Involute gear profiles, to be precise, can only be produced when the tooth is ground in a manner permitting the grinding action of the grinding wheels to be controlled upon different parts of the profiles. The same amount of grinding action should take place at every point in the profile and this is possible, with machines having two wheels, only when the relative movements between the wheels and blank are such that the contact of the wheels with the teeth simultaneously progress along the tooth profiles at uniform speeds. Also this progress of the grinding action must be in the same direction. In gear tooth grinding machines heretofore made which operate with two grinding wheels, the tooth faces of the involute profile have been ground more rapidly than the tooth flanks so that the profile of the tooth is not exactly uniformly ground. This occurs by reason of the fact that the progress of the grinding action along the face of the tooth is faster than along the flank or root portions which are closer to the base circle. Uniform grinding of the profile therefore requires a different rolling speed when the wheel is grinding the tooth faces than when it is grinding the tooth flank portions. This rolling action can be varied by appropriate means for actuating the wheel mountings but of course could not be used in the machines shown in Figs. 12 and 13 as the two grinding wheels engage different parts of the tooth profile at any one instant.

For the same reason in previous forms of gear tooth grinding machines it has been found impossible to vary the tooth form at the face or tip so that it departs slightly from the true involute form. This was not possible for the reason that the tooth engaged by the other wheel would be affected at the flank or root. Fig. 1 represents in plan a diagrammatic view of a machine in which the abrasive wheels always engage similar portions of the tooth curves. These mountings for the wheels are shown in their two extreme operative positions.

In this embodiment of the invention the plane abrasive surfaces of the grinding wheels 9 and 10 are vertically disposed and on a similar level with the blank 8 which, as shown, is mounted on a vertical axis. A drum 7 on the work spindle 15 is, during the grinding operation, fixed against rotation and the gear blank 8 to be ground is directly attached to this spindle 15 carrying the drum 7. The grinding wheels 9 and 10, two of which are shown, are supported upon brackets or frames 16 and 17 which can be moved in a direction parallel to the plane work engaging surface of the wheels 9 and 10. These wheel mountings or frames 16 and 17 are carried upon oscillating arms 18 and 19 which may be oscillated about the axis of the work spindle 15 and drum 7. By means of connecting rods 20 and 21, these arms 18 and 19 carrying the wheel mountings 16 and 17 may be oscillated through any desired angle. Preferably, and as shown, these connecting rods 20 and 21 are actuated by means of a member 24 reciprocated through a limited and fixed distance by means of a rotating cam 25. Oscillating movement of the arms 18 and 19 combined with the movement imparted to the frame 16 and 17 by oppositely disposed flexible bands 5 and 6 attached to the base of the wheel mountings 16 and 17 and extending in opposite directions around the drum 7 on the work spindle 15 effect relative rolling action between the gear tooth blank 8 and the abrasive surface of the wheels 9 and 10.

It will be seen from this figure that the

two wheels 9 and 10 simultaneously engage similar portions of the profiles on opposite sides of different teeth. With the oscillating arms 18 and 19 moving to and fro by reason of the rotation of the driving cam 25 the profile of the teeth from the face to the root of the teeth will be contacted by the abrasive surfaces of the wheels. After each revolution of the cam 25 the wheels 9 and 10 can be withdrawn out of contact with the gear 8 by any well-known means and the gear 8 and its spindle 15 indexed one pitch and again be clamped in position with the drum 7 on the spindle 15 while additional tooth profiles are being ground.

The oscillating movement of the arms 18 and 19 in Fig. 1 is cam controlled so that the angular velocity thereof may be varied as the wheels 9 and 10 engage different portions of the tooth profiles. The contact of an abrasive wheel with the tooth profile as the grinding action progresses along the profile is indicated in the diagram Fig. 2. In this figure the circle Ro is the base circle of the involutes of a gear, two of which are shown. The wheels always engage the profile at the point of tangency of the wheel surface to the involute. If we assume the relative rolling action, represented by rotation of the line OT about the center O, to take place at constant angular velocity a, the portions of the profile 1_1, 1_2, 1_3 become longer per unit of time as the angle A increases and the contact of the wheel is further from the base circle. Less grinding action will take place on the profile therefore as the wheel engages portions farther from the base circle Ro unless means are provided for slowing down the rolling motion. This will be evident from the following taken in connection with Fig. 2.

The angular speed of the tangent line T P is equal to that of the radius O T. Since the length of the tangent P T is equal to the arc $P_oT = Ro \times A$ then the tangential speed V at any point P in the profile is $V = A \times a \times Ro$. So that if we wish to maintain V constant at all portions of the profile

$$A = \frac{\text{const}}{A}$$

The cam groove on disc 25 for controlling the rolling action therefore should be designed with the aid of this equation so that during a constant angular speed of the driving cam the contact point of the wheel on the tooth profile will progress at approximately a constant speed. In this way uniform grinding throughout the length of the tooth profiles is accomplished. It will be also understood that it is possible to continue the grinding action a longer or shorter time upon certain specified portions of the profile, this being accomplished by varying the form of the cam on the driving disc. By so doing a slightly modified form of involute tooth can be ground. In the above described arrangement of parts the two abrasive wheels grind exactly simultaneously, that is, they start and stop their grinding action at the same time. The grinding time, therefore, is materially reduced.

With the mechanism shown in Fig. 1, it has been assumed that the grinding wheels 9 and 10 are of such large diameter that an axial feed of the blank 8 relative to the grinding surfaces would be unnecessary. However, grinding wheels 9 and 10 of smaller diameter may be used and any well-known means for moving the blank 8 or the abrasive wheels 9 and 10 in a direction parallel to the axis of the blank 8 may be used for this feeding movement. This feeding movement may take place during the generating rolling motion of the wheels relative to the blank.

In Figs. 3, 4, 5 and 6 a complete machine is illustrated, unnecessary details of construction being omitted. The oscillating supports 18 and 19, which rest on the arcuate guides 27 and 28 formed on the base 5 of the machine, oscillate about the spindle 15. On these supports 18 and 19 are mounted two slides 3 and 4 supporting the two oscillating frames 29 and 30 and which effect the relative rolling action between the wheels 9 and 10 and the gear blank 8. On the two slides 3 and 4 are mounted the fastening means for the flexible steel bands 5 and 6. These members support one end of each of these flexible bands which have their other or opposite ends respectively fastened to the central cylinder 7 on the spindle 15.

The grinding wheels 9 and 10 are adapted to be driven by motors as shown in Figs. 3 and 5 and are supported upon heads 16 and 17 movable in directions at right angles to each other on the oscillating members 29 and 30. The two oscillating supports 18 and 19 for effecting oscillatory movements of these members 29 and 30 are pivotally connected with a cross head 24 by connecting rods 20 and 21 which are adjustable in length. This cross head 24 is adapted to be reciprocated by a lever 35 which in turn is oscillated by a cam 25 rotated by an appropriate means. The rotation of the cam disc 25 is accomplished by means of a motor 36 driving through a belt and intermediate change speed connections shown diagrammatically in Fig. 6.

The gear 8 to be ground is mounted on a work spindle 50 in alinement with spindle 15 and is clamped between centers on an arbor on the vertical slide 42 which is adapted to be reciprocated by the lever 41. A connecting rod 43 adjustable in length connects lever 41 with another lever 46 which is oscillated by means of an eccentric 44 so that the arm 46 oscillates about the

axis of the pin 45. To change the stroke of the lever 41, the end of the rod 43, which is connected pivotally to the rocking lever 46, can be adjusted in any well-known manner. To rotate the eccentric cam 44 a worm gear 47 is provided which is slowly rotated by a worm 49 driven by a shaft from the motor 36.

The gear 8 to be ground has its spindle 50 connected to indexing mechanism provided with an indexing plate 51. By means of a locking lever 52, which is adapted to be engaged in a notch in the indexing wheel 51, the indexing plate 51 and the gear 8 to be ground are held stationary during the grinding operation. Normally the lever 52 is held in its plate engaging position by means of a spring 52^a. In order to index the gear 8 and spindle 50 one pitch or tooth between successive grinding operations, a rod 55 and the indexing lever 52 to which the rod is connected are withdrawn from the indexing disc 51 by cam 54. Then, by means of cam 69 and a rod 56, which may be suitably adjusted as to its length, the lever 57 and the connecting feed lever 58 are oscillated. This movement of the feed lever 58 causes its pawl 59 to engage a notch and thus index the indexing wheel 51 together with the work supporting spindle 50 and the gear blank 8. As soon as this movement of lever 58 is complete, the indexing lever 52 falls into an adjacent notch of plate 51 which holds the gear 8 and its supporting members against turning movement. The spring 61 then allows the lever 58 and its pawl 59 to return to their initial position for a subsequent indexing operation. The shaft 53 for effecting the indexing movements shown in Fig. 5 is driven at slow speed through a bevel gear segment 62 intermittently meshing with a bevel gear 63 and through two successive pairs of bevel gears 64 and 65, as shown in Fig. 6 of the drawings.

At the respective end positions of the rolling motion of the parts shown in Figs. 3 et seq., a rod 66 on each part (but one of which is shown) is moved in the direction of its axis by means of a cam plate 67 mounted on the frame 5. This motion, as shown in Fig. 8, is transmitted through appropriate oscillating levers to move the abrasive wheel support 16 in such a way that the wheel 9 is drawn back sufficiently from the gear 8 being ground so that it can be indexed without its teeth coming into contact with the periphery of the grinding wheel. In the same manner, also, the opposite grinding wheel support 17 is withdrawn from adjacent the gear at the end position of the rolling movement.

The grinding machine for spur gears illustrated in Fig. 3 et seq. operates in the following manner. The constant rotation of the cam disc 25 actuates the oscillating supports 18 and 19 so that the two grinding wheels 9 and 10 constantly oscillate and swing about the spindle 15 in a manner to effect a rolling motion relative to the fixed gear blank 8. By means of the constant rotation of the cam disc 44, the gear 8 being ground is constantly moved vertically past the wheels 9 and 10. When the cam disc 25, which effects the rolling action of the wheels, assumes a position indicated by full lines in Fig. 3, the grinding supports 3 and 4 are drawn back by means of the cam plates 67. When the cam disc 25 has rotated through one-half a revolution, as indicated in the dotted position of the parts, the grinding wheels 9 and 10 are in engagement with the flanks or bases of the teeth. When the wheels are in their withdrawn position the lever 52 is withdrawn from engagement with the notch in the wheel 51 by means of cam 54, as shown in Fig. 9. This movement of the indexing lever 52 is accomplished by rotation of the shaft 53 through the bevel gear 63 being engaged with and rotated by the gear segment 62 on the cam disc 25. The oscillating movement of the indexing lever 52 is discontinued when the cam disc 25 has rotated a given amount from its position, as shown in Fig. 1. At that time the grinding supports 3 and 4 are withdrawn to their extreme position. While in this position the indexing arm 58 actuated by the cam 69, begins to move in the direction of the arrow and rotates the indexing plate 51 by means of its pawl 59. Rotation of the indexing plate 51 also indexes the work spindle and the gear 8 to be ground. When the cam disc 25 has rotated still further, the feeding movement of the lever 58 is discontinued and the cam 69 is now located directly in alinement with the rod 56. At the same time the rod 55 connected to the indexing lever 52 moves from the cam surface 54 so that the indexing lever 52 falls into a tooth space of the indexing plate 51. By means of the continued rotation of cam 25 the rolling movement of the parts becomes reversed and the feed rods 66 again effect a reverse travel along the cam 67 with the result that the grinding supports are moved again toward the axis of the gear into operative position. In the meantime the feeding lever 58 actuated by spring 61 returns to its initial position and the indexing motion is completed and the grinding supports are again in their initial operative position. From this position the grinding wheels again begin a new cycle of operation upon a subsequent pair of tooth flanks.

During the indexing operation just mentioned, neither the drive for the rolling motion of the wheels nor the driving mechanism for the slide 42 is discontinued. These two motions are discontinued only when the

gear has been completely ground. This continual grinding process, during which none of the main operative parts are stopped, renders an absolutely quiet and reliable grinding operation.

After the conclusion of the grinding operation, the machine can be stopped by any well-known means, as by a cam on the indexing plate, which in turn actuates mechanical or electrical means to stop the main driving motor.

As shown in Fig. 11, production may be increased by mounting two abrasive wheels A and B on each of the heads 16 and 17, these being separated by a distance equal to one or more pitches. One wheel, as indicated at A, may be used for rough grinding the tooth profiles and the wheel B for finishing them.

Referring to the modifications and first to Fig. 12, an embodiment is shown in elemental and diagrammatic form. This figure shows two slides 3′ and 4′ movable parallelly and in opposite directions in suitable bearings provided in fixed portions 1′ and 2′ of a suitable base. These two slides 3′ and 4′ are connected by means of steel tapes 5′ and 6′ extending around and each having one of their ends attached to the drum 7′ on a blank carrying spindle 15′. The opposite ends of the tapes are fastened to the ends of the slides 3′ and 4′. The grinding wheels 9′ and 10′ are supported on suitable brackets and slides, (not shown) the position of their abrasive surfaces only being indicated. As shown in this figure, the position of the wheels 9′ and 10′ is such that one profile of a tooth 13′ is being ground simultaneously with the opposite profile of a tooth 14′ substantially diagrammatically opposed.

The slides 3′ and 4′ are reciprocated by means of an oscillating lever 12′ pivotally mounted upon a pin 11′ and having rollers adapted to contact with the end surfaces of the slides 3′ and 4′. This lever 12′ may be oscillated by any suitable means, such as by the rotating crank 13′ engaged within an elongated slot formed in the lever 12′. This permits the gear 8′ on its spindle 15′ to be rotated simultaneously with the reciprocatory movements of the slides 3′ and 4′ by reason of the bands 5′ and 6′. The motion induced by oscillation of the lever 12′ corresponds to the gear 8 engaging oppositely disposed reciprocating racks, the abrasive surfaces of the wheels being in the position of opposite sides of rack teeth. It will be noted in this embodiment of the invention that one of the wheels 9′ engages the face of a tooth while the wheel 10′ is acting upon the flank of another tooth. The wheels therefore are never in engagement with similar portions of the teeth.

Referring to the embodiment of the invention shown in Fig. 13, the slides 3″ and 4″ are mounted for reciprocatory movement in a member 1″ adapted to be oscillated by means of a crank and connecting rod. By means of tapes 5″ and 6″ having their opposite ends in engagement with the ends of the slides 3″ and 4″ and fastened to a drum 7″, the relative rolling movement between wheels 9″ and 10″ and blank teeth 8″ is effected. The grinding action in this embodiment of the invention is similar to that of the machine in Fig. 1, that is, while the flank of one tooth is being ground the face of the opposite side of a diametrically opposite tooth is being ground. By positioning the wheels correctly, the grinding action of the wheels 9″ and 10″ is entirely simultaneous, that is, they both start to grind simultaneously and complete their grinding operation at the same time so that the time and extent of the rolling motion of the wheels 9″ and 10″ and the blank 8″ may be reduced to a minimum.

What I claim is:

1. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to engage opposite sides of teeth of a gear to be ground, and means to effect a rolling action between said gear and abrasive wheels, whereby said wheels will be simultaneously advanced in the same direction along opposite sides of the profiles of teeth on said gear.

2. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to simultaneously engage opposite sides of teeth of a gear to be ground, means to effect a rolling action between said gear and abrasive wheels, and means to vary the rolling motion while the wheels are in engagement with different portions of the tooth profiles.

3. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to simultaneously engage opposite sides of teeth of a gear to be ground, means to effect a rolling action between said gear and abrasive wheels, and constantly rotating means having a cam to vary the rolling motion of said wheels relative to said gear while the wheels are in engagement with different portions of the tooth profiles.

4. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to simultaneously engage similar portions of opposite sides of teeth of a gear to be ground, means to effect a rolling action

between said gear and abrasive wheels whereby said wheels will be simultaneously advanced in the same direction along opposite sides of the profiles of the teeth, and means to vary the rolling motion while the wheels are in engagement with different portions of the tooth profiles.

5. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to simultaneously engage opposite sides of teeth of a gear to be ground, and means to effect a rolling action between said gear and abrasive wheels, said wheels adapted during their rolling movement always to engage similar portions of the teeth in engagement therewith during said rolling action.

6. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to simultaneously engage opposite sides of teeth of a gear to be ground, means to effect a rolling action between said gear and abrasive wheels, said wheels adapted always to engage similar portions of the teeth in engagement therewith, and means to index said gear between successive rolling actions.

7. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to simultaneously engage opposite sides of teeth of a gear to be ground, means to effect a rolling action between said gear and abrasive wheels, said wheels adapted during their rolling movement always to engage similar portions of the teeth in engagement therewith, and means to oscillate said wheels from said gear between successive rolling actions to effect indexing of said gear.

8. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to simultaneously engage opposite sides of teeth of a gear to be ground, means to effect a rolling action between said gear and abrasive wheels, and means to move said wheels away from said gear at an extreme position of said rolling action.

9. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to simultaneously engage opposite sides of teeth of a gear to be ground, means to effect a rolling action between said gear and abrasive wheels whereby said wheels will be simultaneously advanced in the same direction along opposite sides of the profiles of the teeth, and cam actuated means to simultaneously move said wheels away from said gear at an extreme position of said rolling action.

10. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to engage opposite sides of teeth of a gear to be ground, means to effect a rolling action between said gear and abrasive wheels, and cam means for controlling said rolling action whereby the grinding time may be varied upon different portions of the tooth profiles.

11. A gear tooth grinding machine comprising in combination, a base, a pair of oscillating supports thereon, abrasive wheels rotatably mounted on said supports and adapted to engage opposite sides of teeth of a gear to be ground, means to effect a rolling action between said gear and abrasive wheels, cam means for controlling said rolling action whereby the grinding time may be varied upon different portions of the tooth profiles, and means to index said gear between successive rolling actions.

In testimony whereof, I hereto affix my signature.

ALBERT AEPPLI.