July 10, 1934. H. JACKOWSKI 1,966,172

METHOD OF AND APPARATUS FOR LAPPING GEARS

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Fig. 2

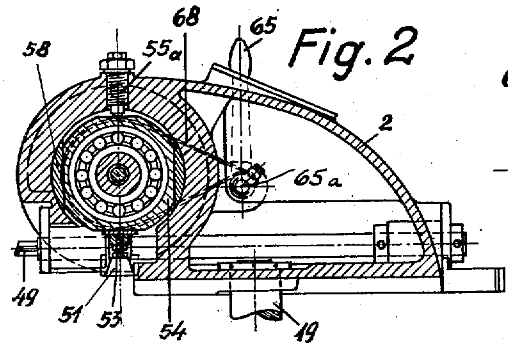


Fig. 3

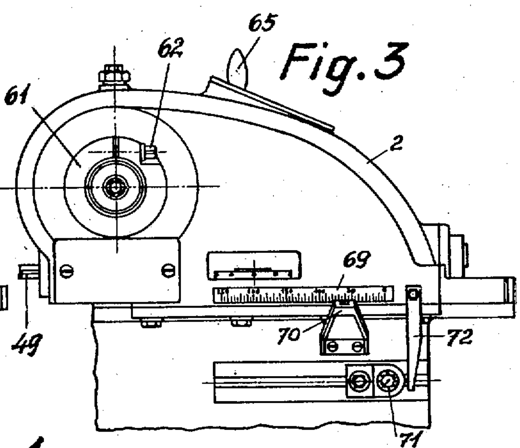
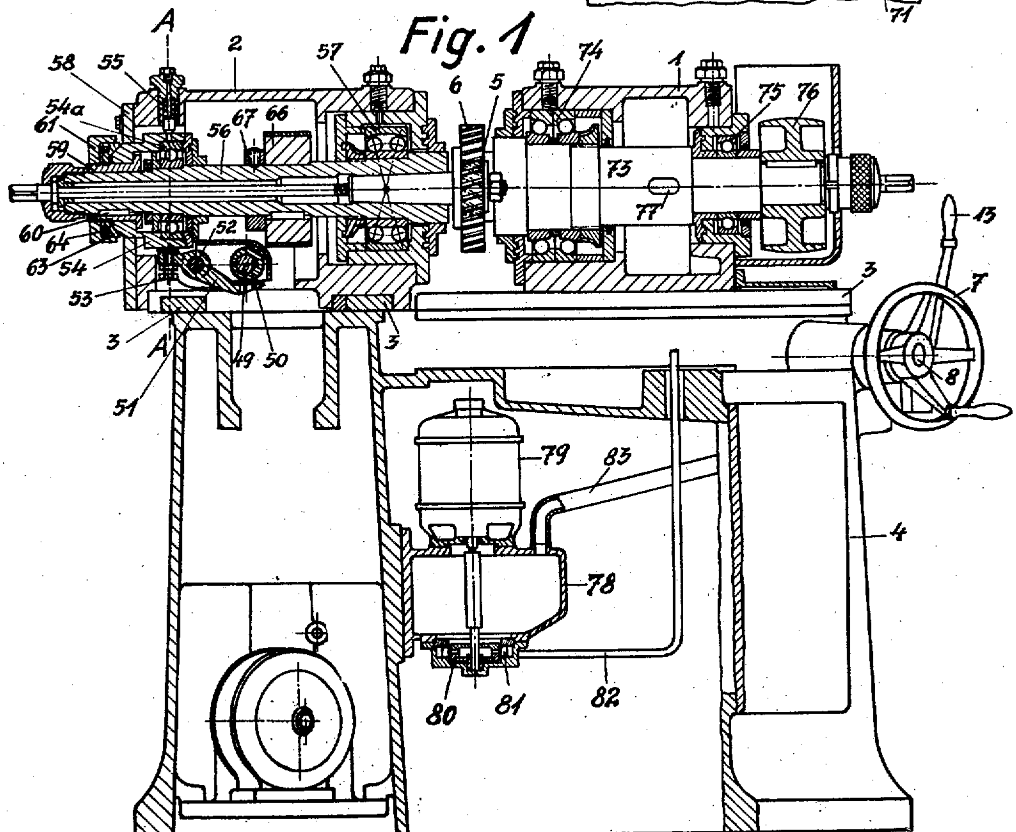


Fig. 1



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METHOD OF AND APPARATUS FOR LAPPING GEARS

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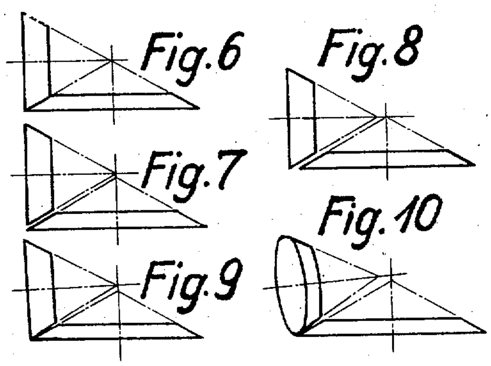
Fig. 6 Fig. 7 Fig. 8 Fig. 9 Fig. 10

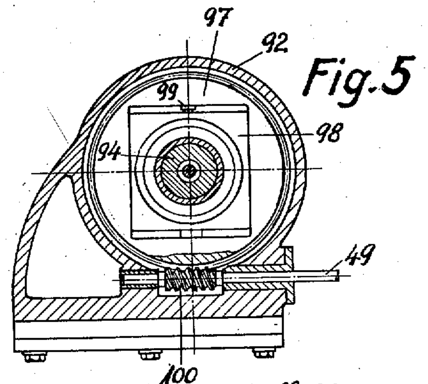
Fig. 5

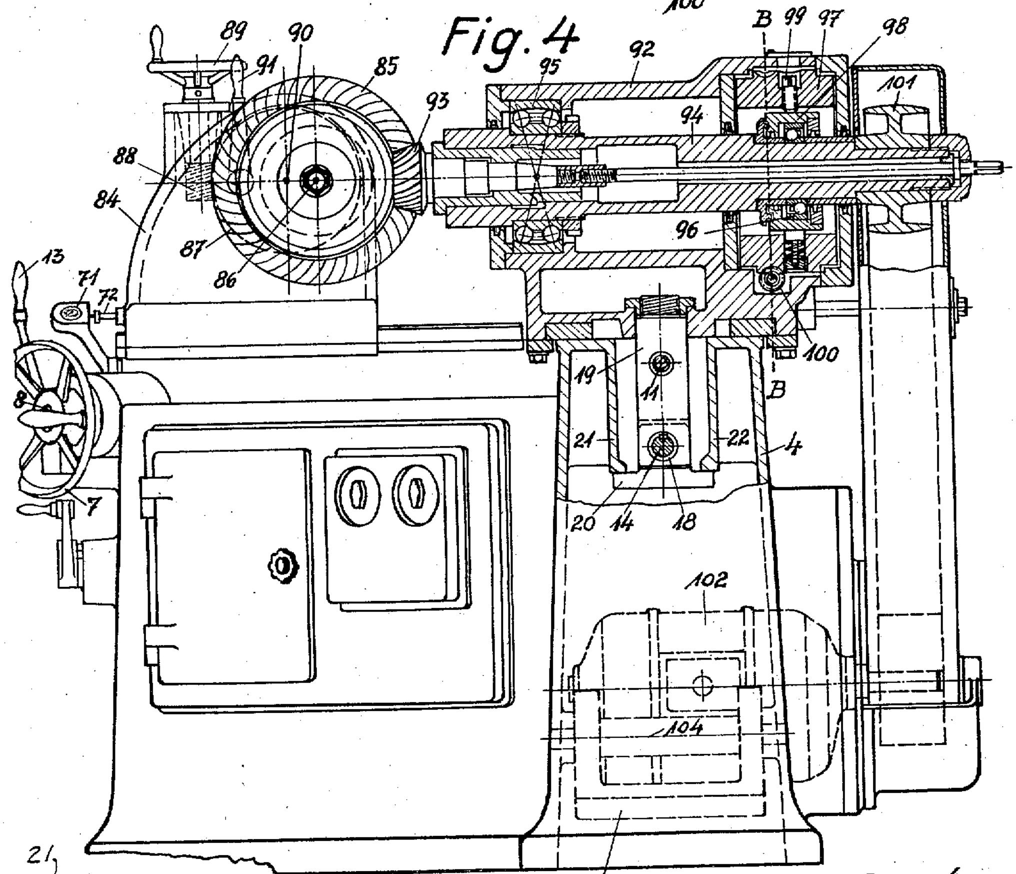
Fig. 4

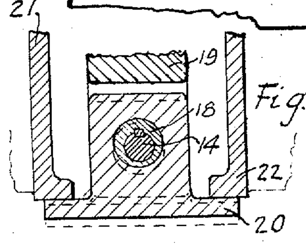
Fig. 11a.

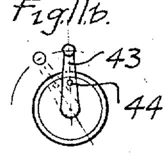
Fig. 11b.

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Fig. 11

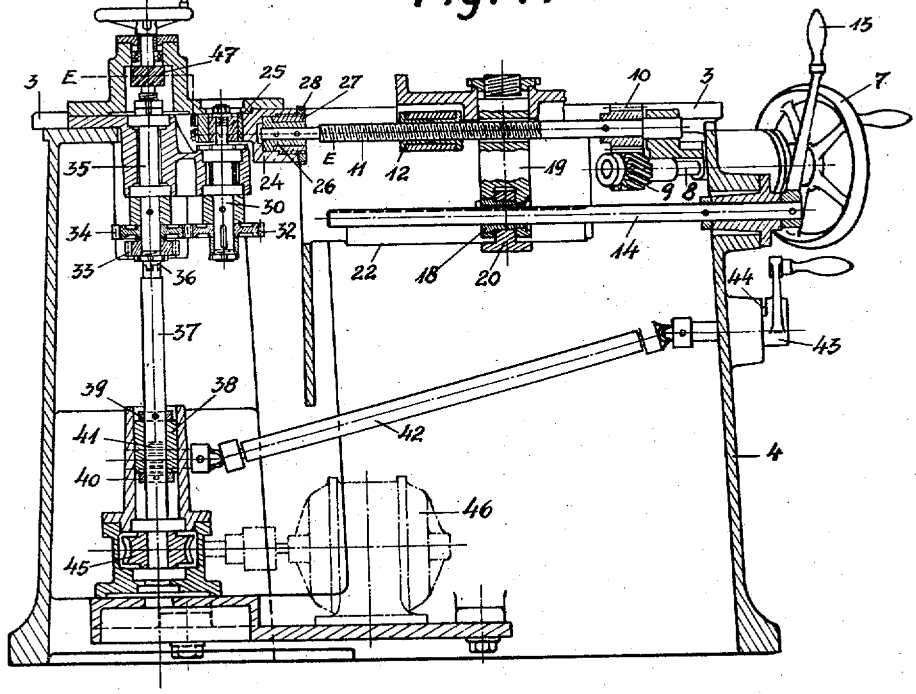

Fig. 12

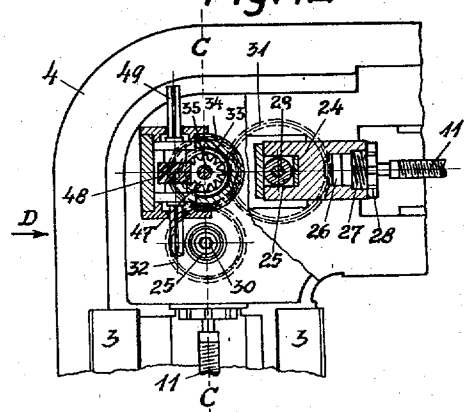

Fig. 17

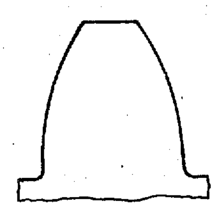

Fig. 18

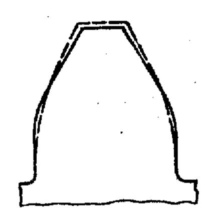

Fig. 19

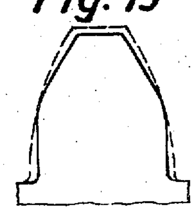

Fig. 20

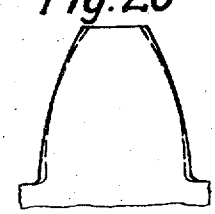

Fig. 13

Fig. 14

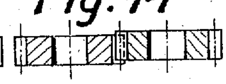

Fig. 15

Fig. 16

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Patented July 10, 1934

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UNITED STATES PATENT OFFICE

1,966,172

METHOD OF AND APPARATUS FOR LAPPING GEARS

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Application February 5, 1931, Serial No. 513,676
In Germany February 11, 1930

16 Claims. (Cl. 51—26)

The invention relates to a method of and machines for, making gears, viz: spur and bevel gears which are insensitive to displacements of their axes from the theoretically correct relative positions, the gears running noiselessly even in cases where the gears change their relative positions while in service.

Another object of the invention is to eliminate deformations or distortions of the tooth profiles which usually occur when grinding and lapping gears, by making them run with a fluid abrasive compound, and also by applying predetermined tooth corrections to the gears to be ground in, to give the gears a maximum possible degree of accuracy of flank profile.

In the accompanying drawings,

Fig. 1 represents a longitudinal section taken through the machine intended for lapping spur gears.

Fig. 2 is a cross section through the headstock of the driven gear, the section being taken on line A—A of Fig. 1.

Fig. 3 is a view of the headstock for the driven gear.

Fig. 4 is a longitudinal section through the machine for lapping bevel gears.

Fig. 5 is a cross section on line B—B of Fig. 4 through the headstock of the driving gear.

Fig. 6 shows two bevel gears in the correct relation.

Figs. 7–10 show two bevel gears in various displaced relative positions.

Fig. 11 is a longitudinal section C—C of Fig. 12 through the base and the mechanism, by which the displacing movements are produced, as seen in the direction of the arrow D.

Fig. 11*a* is a vertical sectional view through bolt 19 along the dotted lines shown in Figs. 4 and 11.

Fig. 11*b* is an end view of the crank 43 of Fig. 11, showing its two positions, one of these positions being indicated by dotted lines.

Fig. 12 is a close-up plan view representing a section E—E of Fig. 11 of the mechanism producing the displacing movements.

Fig. 13 shows two spur gears in the correct engaged positions.

Figs. 14–16 show two spur gears in various displaced relative positions.

Fig. 17 is a correct involute tooth profile of an unhardened tooth.

Fig. 18 is a tooth profile distorted by the hardening effect.

Fig. 19 is a tooth profile which has been deformed by running the gears together in a fixed, rigid position.

Fig. 20 shows a tooth profile with grinding allowance at the top and bottom portions. In each of the Figs. 18, 19 and 20 the correct involute profile is shown in dotted lines.

The efforts to obtain quiet-running spur, helical and bevel gears, in practice, have been essentially confined to the production of gear flanks which are as accurate and smooth as possible. With unhardened gears, the usual shaping methods by applying a planing tool, hub or shaper-cutter have been improved, and furthermore, the gears have been given a surface as smooth as possible by burnishing them in engagement with each other or with hardened master gears with the object of eliminating the tool marks by rolling them together under pressure.

With hardened gears, efforts have been made to eliminate the effect of hardening distortions and to produce a theoretically accurate flank surface which is as smooth as possible by grinding the tooth flanks, or the same result was tried to be obtained by running the hardened gears in a constant, rigid relative position and feeding a fluid grinding compound between the teeth, i. e. by lapping them.

This method, too, failed to result in the desired success. It became evident that the velocity with which the tooth flanks slide upon each other when rolling is largest on the top portion of the tooth and decreases towards the pitch circle line where it drops to zero, that is, a pure rolling motion takes place at this line. From the pitch circle line, the sliding velocity again increases towards the root of the tooth. As a consequence of the different sliding velocities and different densities of grain, the grinding action of the abrasive grains forced between the flanks is also of a different character this action being largest at those zones having the largest sliding movements while it is smallest at the zone of the pitch circle line.

When considering that, normally, by hardening the teeth, a shrinking action takes place so that the unhardened tooth (Fig. 17) after being hardened, approximately takes the outline of Fig. 18, it will be obvious that the tooth thickness has been reduced at the top and bottom of the tooth where the largest stock removal occurs while the thickness has been increased just at that zone where the grinding action is smallest, that is in the pitch circle zone. Thus, when lapping, a profile will be produced (Fig. 19), on which the hardening distortions not only have not been eliminated, but, on the contrary, the departures from the correct involute profile have been intensified.

Even when in the theoretically correct relative positions, such gears are not able to run quietly. Trying to obtain an additional grinding action in the pitch circle zone by running the gears to be lapped in mesh with a properly profiled, hardened master gear, and shifting the gears both axially and radially while running together, failed to prove successful in obtaining a theoretically correct tooth profile, since, as will be seen from Fig. 18, the hardened gear becomes distorted in its outline by the action of the hardening process, and the master gear will be subjected to approximately the same grinding action of the lapping compound as the gear to be corrected.

If, for example, a spur gear *b* has been lapped with a master gear *a*, and the same master gear is used to lap a spur gear *c*, the gears *b* and *c*, due to the increasing and different wear of the master gear *a* when meshing with the various gears *b* and *c*, etc. will show different tooth profiles which fail to give a proper, silent rolling movement. And, finally, for the same reason, the attempt to have a hardened gear run with several master gears with various pressure angles has had no practical success.

This invention is based on the experience that merely the high accuracy of a ground tooth flank does not afford any reliability as to quiet running conditions. It is rather the accuracy of the assembled relative positions that determines the quietness in service. Since, in practice, because of purely economical reasons of manufacture, the assembly and bearing accuracies do not exceed a given limit (in most of cases, hundredths, and in particular cases, thousandths of an inch), even ground gears having, usually, a larger degree of accuracy (up to ten-thousandths of an inch) cannot gain any particular importance.

The invention relates to a method by which it will be possible to make gears that are insensitive to all relative axial displacements from their theoretically correct positions which occur in practice, and that run quietly even when subjected to axial displacements in service and inaccuracies of assembly. This insensitiveness of the tooth flanks is obtained by imparting to the hardened gears those axial displacements to which they may be subjected later on under service conditions when assembled, suitable machines to be described below being used for this purpose on which a fine-grained, fluid lapping compound is fed to the gears while they are running together.

Since, of course, the quietness of rolling gears also depends on the correctness of the tooth profile, it will be necessary for each method of grinding such gears to take care to obtain the correct profile or to re-establish the same, in the case, it should be changed by effect of hardening distortions. Therefore, in order to obtain such a correct tooth profile, the invention embodies another added feature, namely, to give a surplus of stock or grinding allowance to the gears to be made insensitive in accordance with the present method, at the zones of the largest wear of the flanks, before hardening the gears and when toothing them (Fig. 20). The said surplus of material is ground off by employing machines embodying the principle of the inventive idea and by such an amount that the correct involute flank profile will be re-established. In addition, the whole depth of tooth is made higher than normally; this depth of tooth, generally, amounts to 2.16 module, whereas, according to the inventive principle the whole depth of tooth is made equal to from 2.25 to 2.3 module and larger.

With both hardened and unhardened gears, the method simultaneously results in smoothing and polishing the flanks, while, as far as hardened gears are concerned, also the hardening distortions are eliminated. The method consists in clamping the gears to be lapped, which gears must be provided with an allowance at the top and bottom portions, on the lapping machine, and firstly in positioning the headstocks in the theoretically correct relations, as shown by Fig. 6 for bevel gears and by Fig. 13 for spur gears. The displacing movements (see Figs. 7–10 and 14–16) as measured at the place of destination of the gears, then, are adjusted on the machine both as to their amplitudes and in the ratio of their velocities. The machine is next started so that the gears are caused to revolve about their axes, while a fluid grinding compound is forced between their teeth and, furthermore, the displacing mechanism brings the gear axes out of their theoretically correct positions, that is, displaces them one against the other in a similar manner to that of service conditions through the influences of the elasticity of bearings, assembly errors and the like. The combined additional movements in conjunction with the rolling and sliding velocities of the rolling flanks result in a rapid curved movement of the abrasive grains.

In the following, two styles of machines will be described by way of example which are used for making the gears insensitive and polishing them in accordance with the present invention.

The object of the lapping machine is to run the gears to be lapped in engagement under a given pressure, to force a fluid grinding compound between the teeth and to bring the gears while running into the different displaced relative positions as described above.

The displacing movements of the gears may be obtained by the combination of various individual movements. These individual movements may comprise a reciprocating movement in the direction of the axis of one gear, a reciprocating movement at right angles to the latter, and either an up and down swinging motion about the centre of the bearing nearest to one of the gears this bearing being formed as a floating or pendulum bearing, or a waving or wabbling motion, the periods and the amounts of these three movements being different.

To meet the requirements indicated above, namely to imitate the displacements of the gear axes occurring at the place of destination of the gears to be lapped and to impart them to the gears while being lapped, two types of machines are possible: either a combined machine suited for lapping both spur and bevel gears or a machine for lapping spur gears and another one for lapping bevels. In the following description, the second case will be dealt with both a machine for lapping spur gears and a machine for lapping bevel gears being described.

Generally, the lapping machines consist of two headstocks which may be adjusted along two guide ways on a common base the ways being arranged at right angles to each other.

On the machine which may be used for lapping the two kinds of gears, i.e. spur and bevel gears, one of the headstocks is rotatable on a circular plate by 360 degrees so that it will be possible to so set the axis of a spur gear that it will be parallel with that of its mating gear, and to set the axis of a bevel gear to the required angle under which the gears are to be run together.

The machines shown by the illustrations are designed as single-purpose machines which may be used for lapping spur gears and bevel gears, respectively.

With the spur gear lapping machine, Figs. 1, 2, 3, 11, 12, the two headstocks 1 and 2 are movable along the guide ways 3 of the base 4.

The headstock 1 carrying the driving gear 5, may be moved in a straight line in the direction of the gear axis, while the headstock 2 carrying the driven gear 6 may be moved in a straight line along the base in the direction of the depth of tooth.

Common to the above-named machine designs is the mechanism for driving and producing the mentioned displacing movements as well as for adjusting the headstocks. By means of the hand-wheels 7 which are connected to the screw spindles 11 through the shafts 8, helical gear 9 and spur gear 10 (Fig. 11) while said screw spindles, in turn, are connected to the headstocks through nuts 12, the headstocks may be adjusted to the proper centre distance of the gears to be lapped, and secured in these positions by means of the levers 13, when the gears are to be tested for running in a fixed position. Each of the levers 13 is keyed to a splined shaft 14. On each shaft is mounted an eccentric cam 18 which is rotatably mounted in a bolt 19 of the headstocks 1 and 2. The clamps 20 which are vertically adjustable in the bolt 19, contact with the eccentric periphery of the said eccentric cams. By turning the cam 18 by means of the lever 13, the clamps 20 are tightened against the walls 21 and 22 of the base so that the headstocks are securely pressed against the bed ways. The screw spindle 11 is supported at the hand-wheel end side in the base so as to be axially movable, while it engages at the opposite end with the block 24. The block may be adjusted in the direction of the screw spindle axis and surrounds a cam 25. By rotating said cam, the block is axially reciprocated. One end of the screw spindle 11 carries a sleeve 26 which, by means of the bored screw 27, may be tightened against the body of the block 24 and held in position on the block by a check nut 28. The collar of the sleeve 26 may be clamped either securely between the wall of the block and screw or by allowing some slight clearance. Thus, the screw spindle has some axial clearance with respect to the block so that, by this means, it will be possible to finely regulate the reciprocation of the headstocks and to bring about a slight dwell or stop at each end of a stroke.

The eccentric cams 25 are mounted on the vertical shafts 29 and 30 which are supported in the body of the base and carry the change or pick-off gears 31 and 32 at their respective opposite ends. The gear 31 meshes with the gear 33, and the gear 32 with gear 34. The gears 33 and 34 are mounted on the common shaft 35 which connects to the driving shaft 37 over the clutch 36. The driving shaft 37 is supported within the base so as to be axially adjustable, and it carries a sleeve 38 between the collars 39 and 40. Said sleeve, in which the driving shaft is free to rotate, may be axially shifted, but it cannot be turned, and it is provided with rack teeth which are engaged by a spur gear 41 that may be rotated through the universal joint shaft 42, by means of the crank handle 43. The crank handle may be fixed in two positions by the spring-actuated bolt 44. In one of these positions, shaft 37 is shifted downwards, and the clutch 36 is disengaged so that the mechanism driving the displacing movements is thrown out of action. In the other position, the shaft 37 is shifted upwards, and the clutch as well as the displacing mechanism are put into action. The driving shaft 37 is driven through the worm gearing 45 from the motor 46. On the upper end of the shaft 35, a spiral gear 47 is mounted and meshes with another spiral gear 48, the latter driving the splined shaft 49 which may be axially shifted within the spiral gear.

As far as the description beforementioned is concerned, the driving mechanism intended for imitating the practical displacing movements is the same and common to both the spur gear and the bevel gear lapping machines. Considering the spur gear lapping machine, the splined shaft 49 leads to the headstock of the driven gear and drives a cam 50 acting upon a two-armed lever 51 swinging about the bolt 52. The other end of said lever which may be adjusted by the set screw 53, acts upon lifting the bearing block 54 or dropping the same, the spring 55 being provided for maintaining a constant contact between the bearing block and the set screw 53.

The bearing block 54 receives the rear bearing 54*a* of the spindle 56 which is supported at the front end by the bearing 57. The bearing block 54 slides vertically within the guide 58. When the cam 50 rotates and the lever 51 moves up and down, the spindle swings about the centre of the pendulum bearing 57 in a vertical plane through the axis of the spur gear.

On the axis of the driven gear, two different brakes are arranged one of them acting as a permanent brake under light pressure, while the other one serves as a hand brake permitting the use of a very high braking force. The object of the permanent brake is to provide for a permanent, positive bearing of the tooth flanks of the gears to be lapped and for a uniform, permanently acting pressure between the adjacent flanks. The end of the spindle 56 carries a collared bushing 59 secured against rotation by the key 60. The collar of the bushing contacts with the wall of the bearing block 54. A split nut 61 is screwed on to the bushing; after this nut has been adjusted, it may be locked against self-loosening by the screw 62. Within the nut, a ring 63 having a conical surface is forced against the conical surface of the bearing block 54 by the coiled springs 64. The braking force is brought about by the frictional contact between these two conical surfaces.

The hand brake which may be actuated by the hand lever 65 pivoted at 65ª (see Fig. 2), consists of a drum 66 which is keyed to the spindle and held in position by means of the adjusting ring 67. The braking band 68 which may be tightened or relieved by turning the shaft by the aid of lever 65 is placed round the drum.

The variable distance between the centres of the spindles may be observed on the rule 69 with vernier 70. In addition, a dial micrometer 71 is provided for each of the two headstocks so as to be adjustable on the machine base, and a finger touches the point of each micrometer in order to show the readings corresponding to the amplitudes of the individual displacing movements.

The headstock 1 receiving the driving gear 5 carries the spindle 73 supported radially and axially by the anti-friction bearings 74 and 75. The spindle is driven from the belt pulley 76. Two grooves 77 which may be engaged by an adjustable bolt mounted in the wall of the headstock prevent the spindle from rotation when the gears are to be clamped or removed.

The pump feeding the lapping compound is also common to the feasible kinds of machine designs mentioned above. It comprises a container 78 to which is screwed the motor 79 the shaft extension of the latter carrying a paddle wheel 80 provided with spiral blades or paddles the direction of which is opposite to the direction of rotation of the paddle wheel as well as to the spiral direction of the guide-blades 81 provided in the pump body. The paddle wheel has no metallic contact with the pump body so that any wear of the pump caused by the supply of the lapping compound is done away with. The pump acting by centrifugal force presses the lapping compound through the spiral guide-blades 81 of the body 78 into the hose 82 which feeds it between the teeth of the gears. The used compound is returned to the container through the hose 83.

The single-purpose machine as used for lapping bevel gears, Figs. 4, 5, 11, 12, only differs from the design just described by the position of the two headstocks which are at right angles to each other.

The headstock 84 for the driven gear 85 carries a spindle in an eccentric sleeve 87 which may be rotated by means of hand wheel 89 through worm and worm gear 88 whereby the centre axis 86 of the gear may be placed above or below the centre 90 of the sleeve 87, and therefore also above or below the centre of the driving bevel gear so that gears having crossing axes may also be lapped in contradistinction to gears with intersecting axes.

The permanent brake is arranged in this headstock just in the same manner as in the headstock of the spur gear lapping machine. Likewise, a hand brake is provided and may be actuated by the lever 91.

The headstock 92 for the driving gear 93 carries the spindle 94 in two antifriction bearings, namely in the front pendulum bearing 95 and in the second bearing 96. The second bearing 96 rests in a rotatable sleeve 97 provided with a worm gear cut into its periphery, the bearing being arranged in a guide block 98 which may be vertically adjusted within a square recess of the sleeve 97 by means of the set screw 99 so that the centre axis of the bearing 96 may be made parallel with the centre axis of the sleeve 97. By this procedure, the centre axis of the spindle may be inclined. When rotating the sleeve 97 by turning the worm 100, the spindle axis is caused to perform a three-dimensional waving or wabble motion about the centre point of the pendulum bearing 95 which represents the stationary pole. As a consequence, the bevel gear 93, too, performs a similar three-dimensional wabble motion which, together with the straight line reciprocations of the two headstocks imitates the displacing movements occuring under service conditions. The worm 100 is mounted on the shaft 49 and is rotated by the same, when the mechanism described above and shown in Figs. 11 and 12, is put into action to imitate the actual displacing movements.

At one end, the spindle 94 carries a belt pulley 101 which is driven from a motor 102 built into the bottom of the machine base. Said motor is mounted on a plate 103 which swings about an axis 104 to enable the motor to follow the changing positions of the belt pulley 101. To absorb vibrations the plate 103 is damped in its movements through the section of a plunger moving within a cylinder and displacing oil through narrow circulation passages.

The mechanism for producing the remaining displacing movements is just the same as that described for the spur gear lapping machine.

What I claim as my invention is:

1. The method of lapping gears to make them run silently, which consists in placing pairs of conjugate gears in the meshed relation which they occupy in service, rotating the gears while supplying fluid grinding compound between the gear teeth, and periodically producing relative displacements of the gear axes to simulate the displacements they receive in service, by subjecting the gears to three dimensional relative movements.

2. The method of lapping gears to make them run silently which consists in placing pairs of conjugate gears in the meshed relation which they occupy in service, rotating the gears while supplying fluid grinding compound between the gear teeth, and subjecting the gears to three dimensional relative movements of different amounts and at different speeds.

3. The method of producing silently running gears which consists in forming the teeth of gears with surplus material at the top and root portions thereof, placing pairs of conjugate gears in correct meshing relation, and then lapping them with fluid abrasive while subjecting them to three dimensional relative movements simulating all of the movements which they can receive in service.

4. A spur lapping machine comprising two headstocks capable of relative movement; two parallel rotatable gear supporting spindles, one in each of said headstocks; means for imparting to one of said headstocks a reciprocating motion along the axis of its spindle; means for imparting a reciprocating motion to the other headstock; and means for imparting a wabble motion to the spindle of the other headstock independently of its reciprocating motion.

5. A machine for lapping bevel gears comprising a base carrying two headstocks capable of relative rotational movement; a gear supporting spindle in each of said headstocks, said spindles being angularly disposed one to the other; means for imparting straight line reciprocatory movement to one of said headstocks in a direction perpendicular to its spindle axis; means for imparting reciprocatory motion to the other headstock perpendicular to its spindle axis; means for subjecting the spindle of one of said headstocks to a wabble motion; and means for varying the period and extent of said wabble motions independently of the other motions.

6. A machine for lapping bevel gears comprising a base carrying two headstocks capable of relative rotational movement; a gear supporting spindle in each of said headstocks, said spindles being angularly disposed one to the other; means for imparting straight line reciprocatory movement to one of said headstocks in a direction perpendicular to its spindle axis; means for imparting reciprocatory motion to the other headstock perpendicular to its spindle axis; motor-operated means for subjecting the spindle of one of said headstocks to a wabble motion; and eccentric

means for varying the periodicity of said wabble motion.

7. A machine for lapping bevel gears comprising a base carrying two headstocks capable of relative rotational movement; a gear supporting spindle in each of said headstocks, said spindles being angularly disposed one to the other; means for imparting straight line reciprocatory movement to one of said headstocks in a direction perpendicular to its spindle axis; means for imparting reciprocatory motion to the other headstock perpendicular to its spindle axis; motor-operated means for subjecting the spindle of one of said headstocks to a wabble motion; eccentric means for varying the periodicity of said wabble motion; and means for damping the movements of said motor-operated means.

8. A machine for lapping gears comprising a frame carrying two headstocks; a gear-supporting spindle rotatable in each of said headstocks; means for moving each of said headstocks in a direction at right angles to its spindle axis; means for raising and lowering one of said spindles; and means for swinging one of said spindles bodily about an axis perpendicular to its own axis.

9. A machine for lapping gears comprising a frame; a plurality of headstocks mounted on said frame; a gear-supporting spindle in each of said headstocks; means for reciprocating each of said headstocks toward and away from the other headstock; and micrometer means on said frame for measuring the amount of the reciprocations.

10. A gear lapping machine comprising two headstocks capable of relative movement; two parallel work supporting spindles, one in each of said headstocks; means for imparting to one of said headstocks a reciprocating motion along the axis of its spindle; means for imparting a reciprocating motion to the other headstock; means for imparting a wabble motion to the spindle of said other headstock; and means for supplying fluid abrasive compound under pressure to the work surfaces.

11. A machine for lapping bevel gears, comprising a base carrying two headstocks capable of relative rotational movement; a gear supporting spindle in each of said headstocks, said spindles being angularly disposed one to the other; means for imparting straight line reciprocatory movement to one of said headstocks in a direction perpendicular to its spindle axis; means for imparting reciprocatory motion to the other headstock perpendicular to its spindle axis; motor operated eccentric means for subjecting the spindle in said other headstock to a wabble motion; and means for varying the period and extent of each of the motions independently of the other motions.

12. A machine for lapping gears, comprising a frame; a plurality of headstocks mounted on the frame; a gear supporting spindle in each of said headstocks; means for reciprocating each of said headstocks; means for imparting a wabble motion to one of said spindles; a motor for imparting the wabble motion to said gear supporting spindle; and means for damping the vibrations of said driving motor.

13. A machine for lapping gears, comprising a frame carrying two headstocks; a gear supporting spindle rotatable in each of said headstocks; means for imparting straight line reciprocatory movements to each of said headstocks; means for imparting a wabble motion to one of the two spindles; and means for adjusting one of said spindles to positions above or below the center of the other spindle.

14. A machine for lapping gears, comprising a frame carrying two headstocks; a gear supporting spindle rotatable in each of said headstocks; means for reciprocating each of said headstocks; and means for swinging one of said spindles bodily about an axis perpendicular to itself.

15. A gear lapping machine, comprising two headstocks capable of relative rotational movement; two work supporting spindles, one in each of said headstocks; means for imparting to both of said headstocks a reciprocating motion; means for imparting a wabble motion to the spindle of one of the two headstocks; and means for supplying fluid abrasive compound under pressure to the work carried by said spindles.

16. The method of producing silently running intermeshed gears, which consists in forming the hardened gear teeth with excess material at the top and root portions and projecting beyond the confines of the correct involute profile, placing pairs of conjugate gears in correct meshing relation, and then lapping the gears with fluid abrasive while rotating them and subjecting the two gears to movements relative to each other in three planes until the excess material is ground away and the profile of the finished gear is shaped to correct involute form.

HERMANN JACKOWSKI.

CERTIFICATE OF CORRECTION.

Patent No. 1,966,172. July 10, 1934.

HERMANN JACKOWSKI.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, line 114, claim 4, after "spur" insert the word gear; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of August, A. D. 1934.

Leslie Frazer

(Seal) Acting Commissioner of Patents.

means for varying the periodicity of said wabble motion.

7. A machine for lapping bevel gears comprising a base carrying two headstocks capable of relative rotational movement; a gear supporting spindle in each of said headstocks, said spindles being angularly disposed one to the other; means for imparting straight line reciprocatory movement to one of said headstocks in a direction perpendicular to its spindle axis; means for imparting reciprocatory motion to the other headstock perpendicular to its spindle axis; motor-operated means for subjecting the spindle of one of said headstocks to a wabble motion; eccentric means for varying the periodicity of said wabble motion; and means for damping the movements of said motor-operated means.

8. A machine for lapping gears comprising a frame carrying two headstocks; a gear-supporting spindle rotatable in each of said headstocks; means for moving each of said headstocks in a direction at right angles to its spindle axis; means for raising and lowering one of said spindles; and means for swinging one of said spindles bodily about an axis perpendicular to its own axis.

9. A machine for lapping gears comprising a frame; a plurality of headstocks mounted on said frame; a gear-supporting spindle in each of said headstocks; means for reciprocating each of said headstocks toward and away from the other headstock; and micrometer means on said frame for measuring the amount of the reciprocations.

10. A gear lapping machine comprising two headstocks capable of relative movement; two parallel work supporting spindles, one in each of said headstocks; means for imparting to one of said headstocks a reciprocating motion along the axis of its spindle; means for imparting a reciprocating motion to the other headstock; means for imparting a wabble motion to the spindle of said other headstock; and means for supplying fluid abrasive compound under pressure to the work surfaces.

11. A machine for lapping bevel gears, comprising a base carrying two headstocks capable of relative rotational movement; a gear supporting spindle in each of said headstocks, said spindles being angularly disposed one to the other; means for imparting straight line reciprocatory movement to one of said headstocks in a direction perpendicular to its spindle axis; means for imparting reciprocatory motion to the other headstock perpendicular to its spindle axis; motor operated eccentric means for subjecting the spindle in said other headstock to a wabble motion; and means for varying the period and extent of each of the motions independently of the other motions.

12. A machine for lapping gears, comprising a frame; a plurality of headstocks mounted on the frame; a gear supporting spindle in each of said headstocks; means for reciprocating each of said headstocks; means for imparting a wabble motion to one of said spindles; a motor for imparting the wabble motion to said gear supporting spindle; and means for damping the vibrations of said driving motor.

13. A machine for lapping gears, comprising a frame carrying two headstocks; a gear supporting spindle rotatable in each of said headstocks; means for imparting straight line reciprocatory movements to each of said headstocks; means for imparting a wabble motion to one of the two spindles; and means for adjusting one of said spindles to positions above or below the center of the other spindle.

14. A machine for lapping gears, comprising a frame carrying two headstocks; a gear supporting spindle rotatable in each of said headstocks; means for reciprocating each of said headstocks; and means for swinging one of said spindles bodily about an axis perpendicular to itself.

15. A gear lapping machine, comprising two headstocks capable of relative rotational movement; two work supporting spindles, one in each of said headstocks; means for imparting to both of said headstocks a reciprocating motion; means for imparting a wabble motion to the spindle of one of the two headstocks; and means for supplying fluid abrasive compound under pressure to the work carried by said spindles.

16. The method of producing silently running intermeshed gears, which consists in forming the hardened gear teeth with excess material at the top and root portions and projecting beyond the confines of the correct involute profile, placing pairs of conjugate gears in correct meshing relation, and then lapping the gears with fluid abrasive while rotating them and subjecting the two gears to movements relative to each other in three planes until the excess material is ground away and the profile of the finished gear is shaped to correct involute form.

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