April 16, 1963 H. J. FINDLEY 3,085,369

GEAR FINISHING

Filed March 3, 1959 5 Sheets-Sheet 1

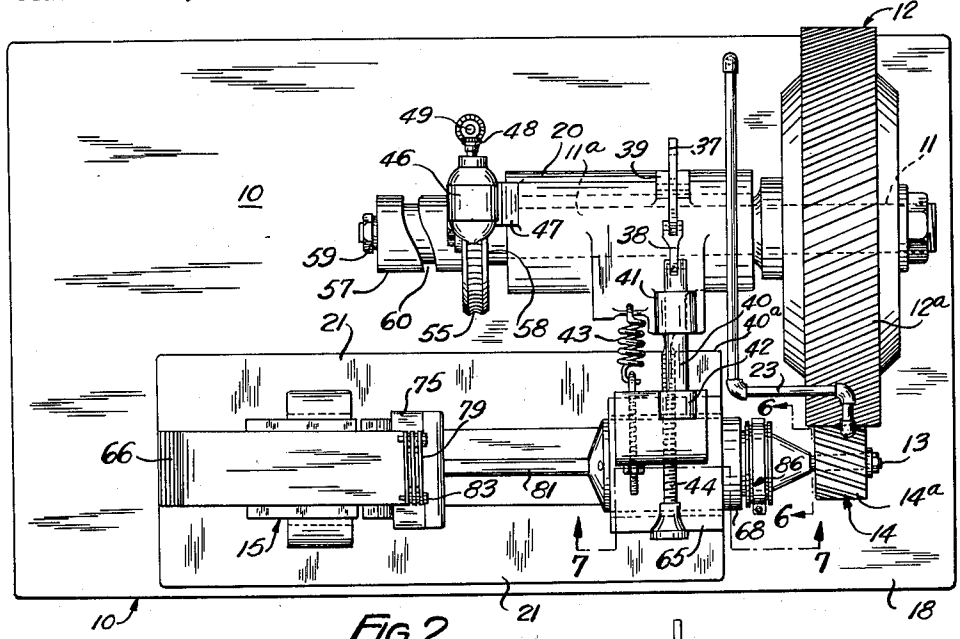


FIG. 2

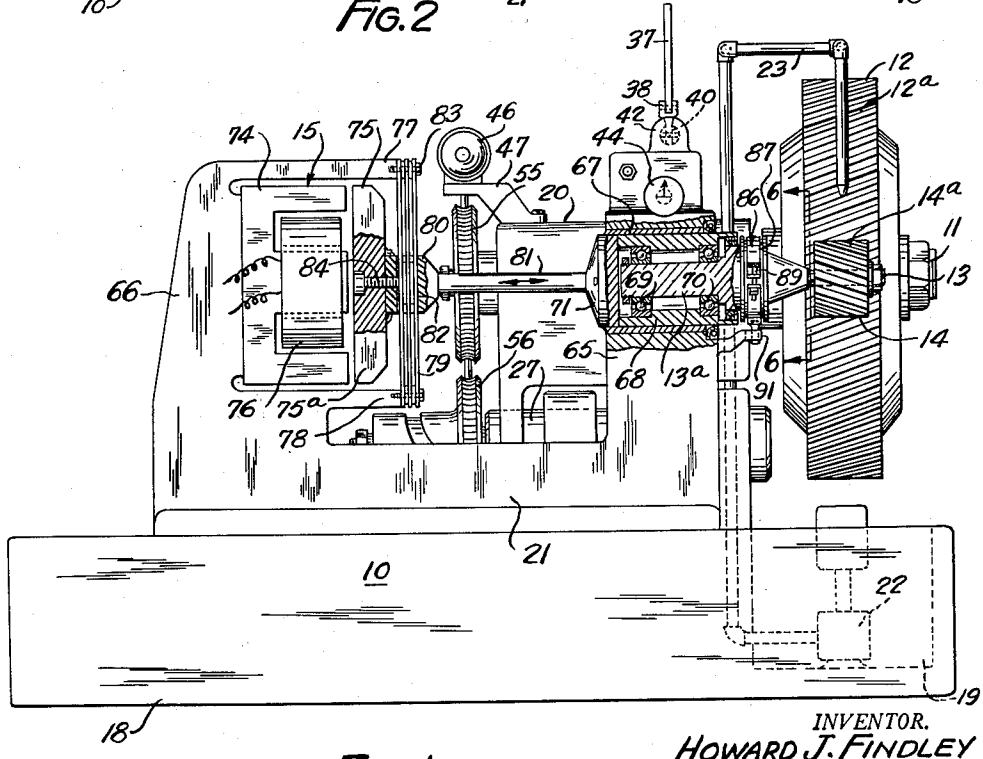


FIG. 1

INVENTOR.
HOWARD J. FINDLEY
BY Hudson, Boughton, Williams, David & Hoffmann
ATTORNEYS

April 16, 1963 H. J. FINDLEY 3,085,369

GEAR FINISHING

Filed March 3, 1959 5 Sheets-Sheet 2

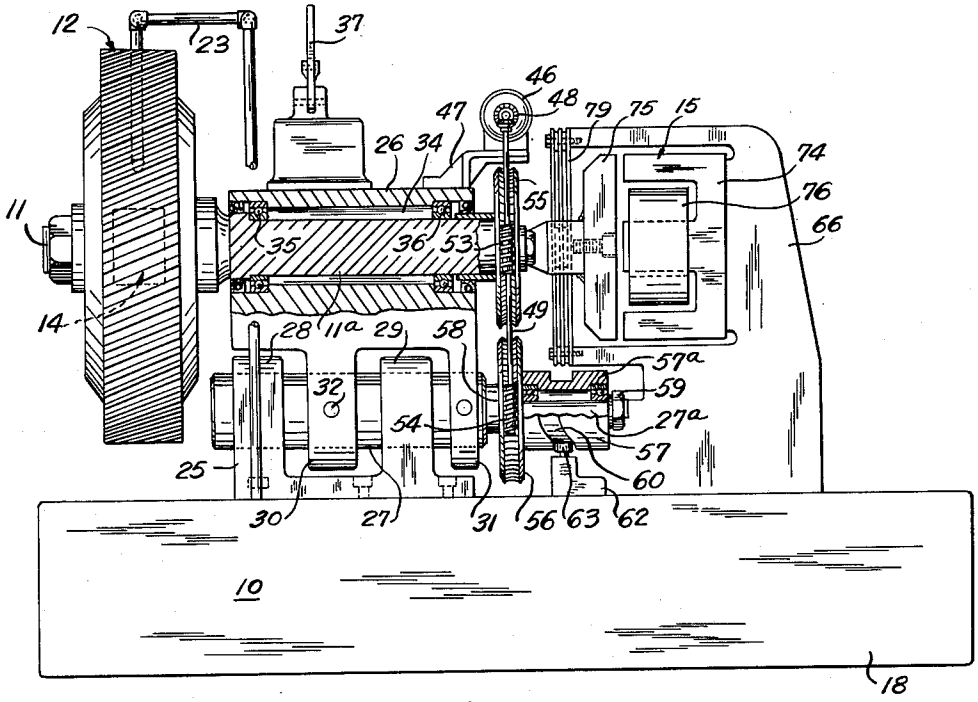


FIG. 3

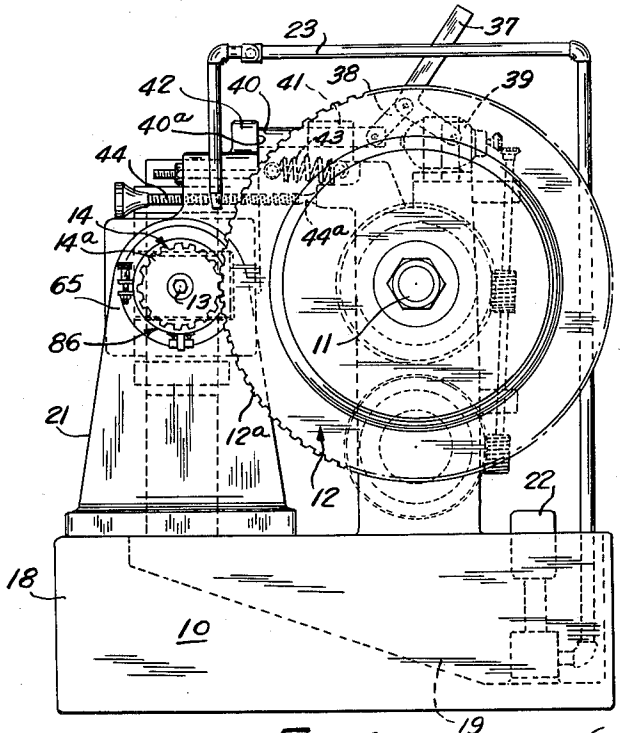


FIG. 4

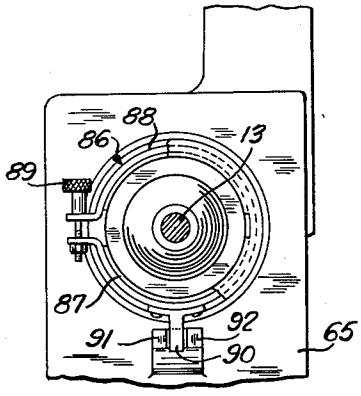


FIG. 6

INVENTOR.
HOWARD J. FINDLEY
BY Hudson, Boughton, Williams, David & Hoffmann
ATTORNEYS

April 16, 1963 H. J. FINDLEY 3,085,369

GEAR FINISHING

Filed March 3, 1959 5 Sheets-Sheet 3

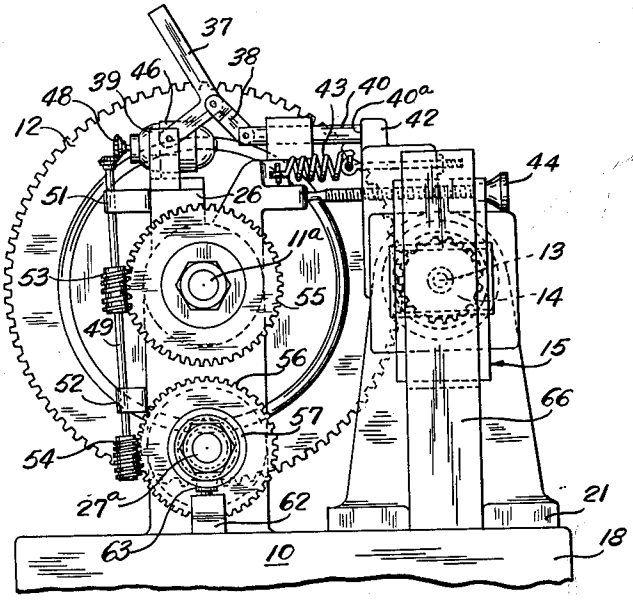


FIG. 5

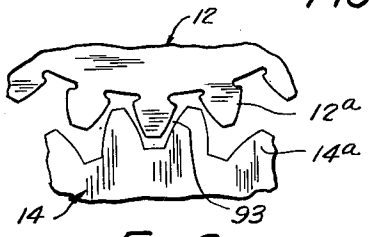


FIG. 8

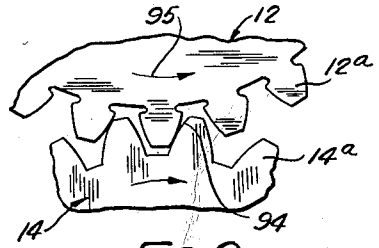


FIG. 9

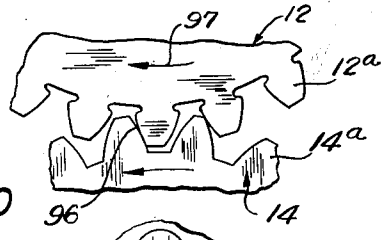


FIG. 10

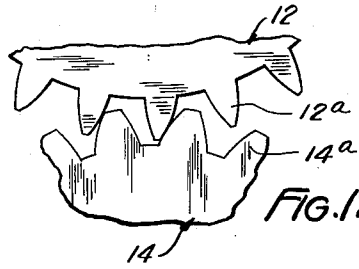


FIG. 12

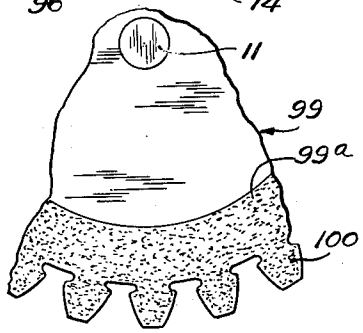


FIG. 11

INVENTOR.
HOWARD J. FINDLEY
BY Hudson, Boughton, Williams, David & Hoffmann
ATTORNEYS

April 16, 1963 H. J. FINDLEY 3,085,369

GEAR FINISHING

Filed March 3, 1959 5 Sheets-Sheet 4

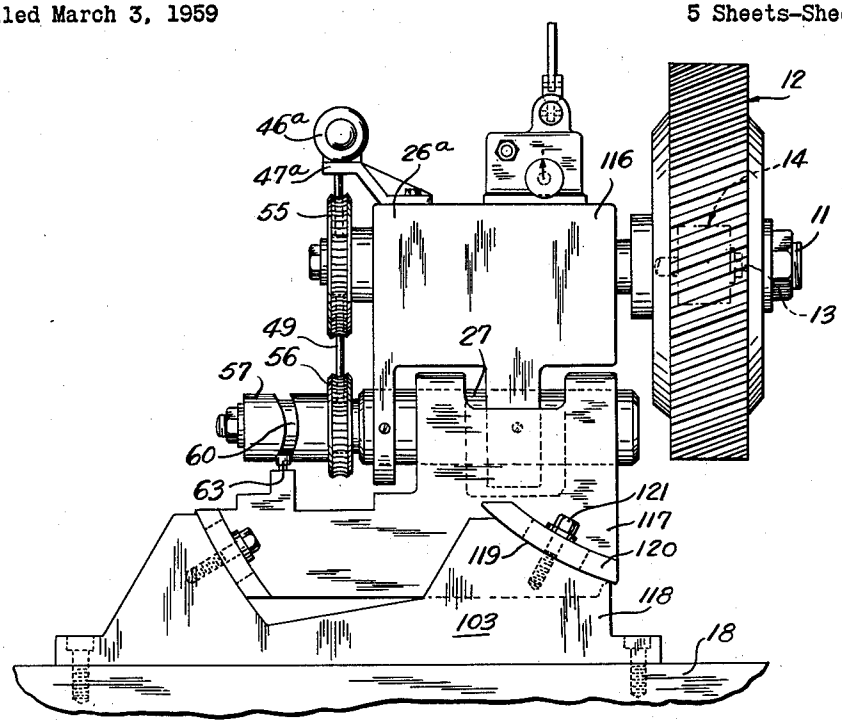


FIG. 14

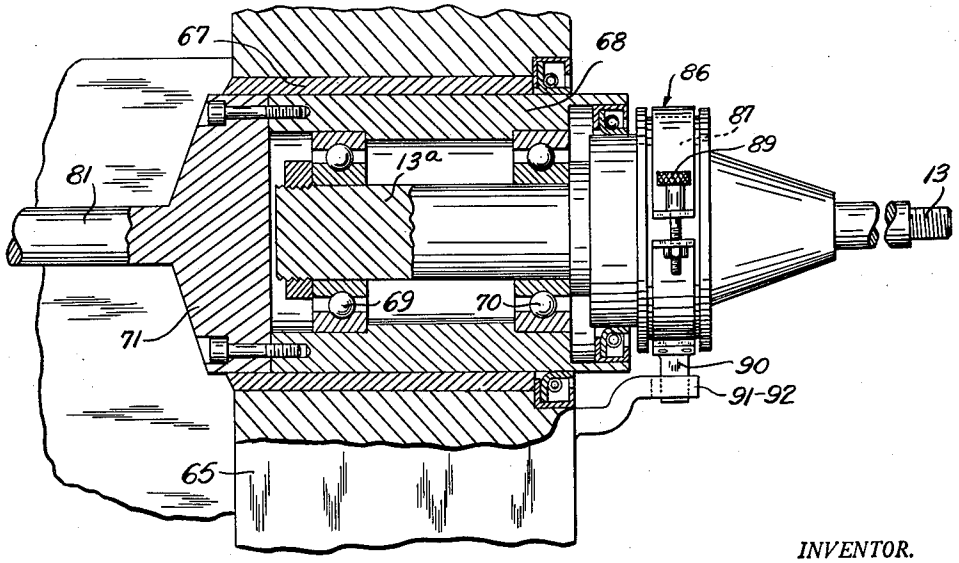


FIG. 7

INVENTOR.
HOWARD J. FINDLEY
BY Hudson, Boughton, Williams, David & Hoffmann
ATTORNEYS

April 16, 1963 H. J. FINDLEY 3,085,369

GEAR FINISHING

Filed March 3, 1959 5 Sheets-Sheet 5

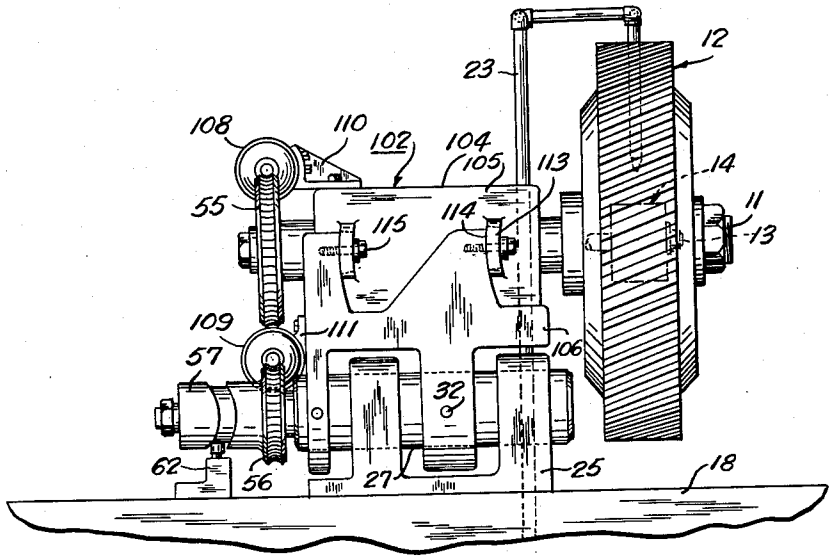


FIG. 13

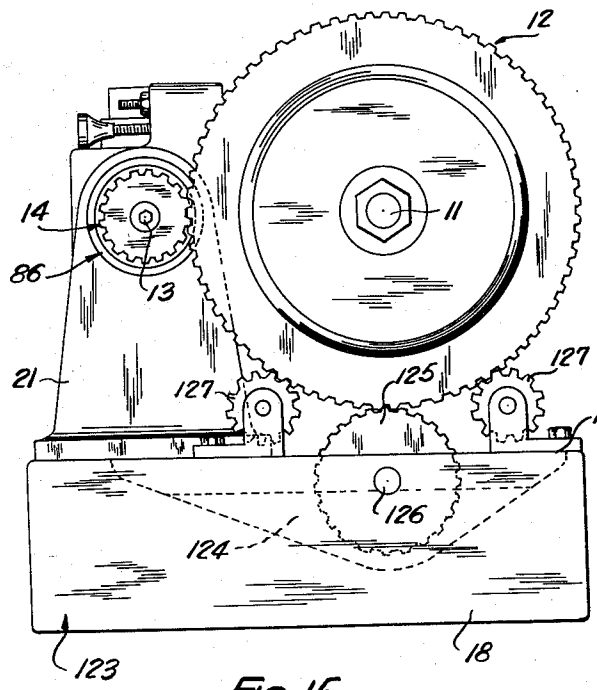


FIG. 15

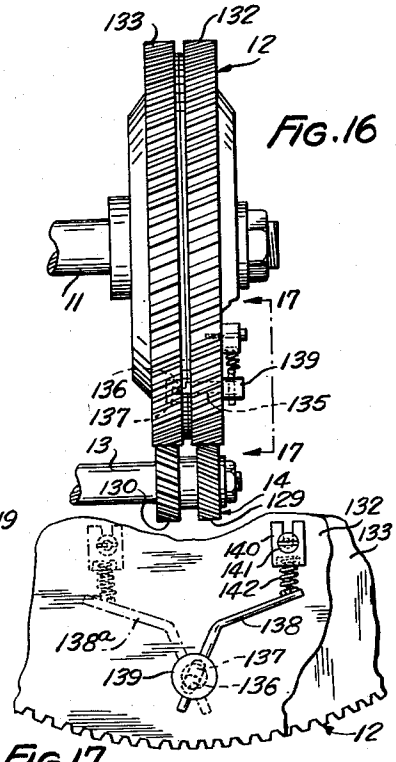


FIG. 16

FIG. 17

INVENTOR.
HOWARD J. FINDLEY
BY Hudson, Boughton, Williams, David & Hoffmann
ATTORNEYS

United States Patent Office 3,085,369 Patented Apr. 16, 1963

3,085,369

GEAR FINISHING

Howard J. Findley, 995 Richmond Road, Lyndhurst, Ohio

Filed Mar. 3, 1959, Ser. No. 796,864
2 Claims. (Cl. 51—52)

This invention relates to the finishing of toothed members, including hardened gears and the like, for the removal of nicks and irregularities so as to leave the gears in a desired accurate and regular condition and with the tooth faces thereof in a smooth state. The invention provides a novel method and apparatus for carrying out such finishing in a rapid and economical manner by producing a rotative, or rotative and traversing, relative movement between a toothed or gear-shaped tool member and a gear member in meshed engagement, and imparting a short-stroke rapid vibratory movement to at least one of the members concurrently with the meshed rotative relative movement.

The present invention also provides a novel vibratory method and apparatus for finishing gears and the like in the manner just above referred to and by the use of an abrading action between the meshed portions of the tool member and gear.

As another important object thereof, this invention provides a novel gear finishing method and apparatus employing an abrading action and wherein the toothed tool member comprises wear-resistant plastic material, preferably nylon.

Still another object is to provide a gear finishing method and apparatus of the character mentioned above and which are applicable to gears of the helically-toothed type and also to gears comprising a group of axially adjacent gear elements.

A further object is to provide for carrying out the gear finishing procedures of this invention with the gear and toothed tool member in a crossed-axes relation.

Additionally, this invention provides a novel method and apparatus for carrying out the gear finishing procedures by so controlling the relative rotative and traverse movements between the gear and tool members as to effectively finish the opposite faces of the gear teeth in a practical and efficient manner.

Other objects and advantages of this invention will be apparent in the following detailed description and in the accompanying drawings forming a part of this specification and in which

FIG. 1 is a side elevation of one side of a gear finishing machine provided by this invention and which can be used to advantage in carrying out the method hereof, portions of the machine being shown in section;

FIG. 2 is a top plan view of the machine;

FIG. 3 is a side elevation of the machine from the opposite side thereof and with portions shown in section;

FIG. 4 is an end elevation of the machine as seen from the tool spindle end thereof;

FIG. 5 is an end elevation of the machine from the opposite end thereof;

FIG. 6 is a partial vertical section taken on line 6—6 of FIGS. 1 and 2 and showing the work spindle brake means on a larger scale;

FIG. 7 is a partial vertical section taken on section line 7—7 of FIG. 2 and showing the work spindle mounting means on a larger scale;

FIG. 8 is a fragmentary end elevation showing the meshed engagement between the gear-shaped tool member and the gear to be finished;

FIG. 9 is a fragmentary elevation similar to FIG. 8 but showing working contact of the tool member with one face only of the gear teeth;

FIG. 10 is a similar fragmentary elevation showing working contact of the tool member with the opposite face of the gear teeth;

FIG. 11 is a fragmentary elevation of an abrasive-carrying tool member suitable for use in the machine and method of this invention;

FIG. 12 is a fragmentary elevation showing a worn condition of the tool member;

FIG. 13 is a side elevation showing a gear finishing machine of a modified construction providing for a crossed-axes relation between the tool member and gear;

FIG. 14 is a similar side elevation showing another modified construction by which such a crossed-axes relation is obtainable;

FIG. 15 is an end elevation showing the machine equipped with a modified form of abrasive supply means;

FIG. 16 is a fragmentary side elevation showing a modified form of gear-shaped tool member by which a group of axially adjacent gear elements can be finished; and

FIG. 17 is a fragmentary end elevation illustrating an adjusting means embodied in the tool member of FIG. 16, the view being taken as indicated by the directional line 17—17 thereof.

The gear finishing machine **10** of FIGS. 1 to 7 inclusive represents one preferred embodiment of the apparatus of this invention and is provided with a tool spindle **11** having a toothed or gear-shaped tool member **12** mounted thereon, and a work spindle **13** located adjacent the tool spindle and on which a gear member **14** to be finished is adapted to be mounted. The spindles **11** and **13** are suitably mounted in the machine so as to provide for meshed rotative and relative traverse movements between the tool member **12** and the gear **14**. The machine **10** also includes a vibrator **15** for producing a short-stroke rapid vibratory movement and applying the same to at least one of the meshed tool and gear members **12** and **14** during the rotative, or rotative and traverse movements, between these members.

The operation of the tool member **12** in meshed engagement with the gear member **14** produces a desired finishing of the tooth faces of the latter and, depending upon the characteristics of the tool member, the finishing operation can be a shaving or burnishing operation performed on the gear member prior to the hardening thereof or can be an abrading-type of finishing operation performed on the tooth faces of a hardened gear member.

When the machine **10** is equipped with a tool member **12** intended for carrying out an abrading-type of finishing operation on the gear member **14** the tool member is preferably, though not necessarily, made of a wear-resistant plastic material, preferably nylon. The use of a gear-shaped tool member made of nylon in the abrasive finishing of gears is a broad concept of this invention and produces advantageous results independently of the use of the short-stroke rapid vibratory movement mentioned above. Likewise, the application of the short-stroke rapid vibratory movement concurrently with a rotative, or rotative and traverse, movement between a gear-shaped tool member and gear is a broad concept of this invention and produces advantageous results independently of the

use of a nylon tool member. Since the gear-shaped tool made of nylon and the application of the short-stroke rapid vibratory movement are features of dominant importance in this invention, the method and the machine **10** will be initially described as having both of these features embodied therein.

The machine **10** can be used for finishing a gear member having helically disposed teeth as well as for finishing gear members of the kind having straight teeth and commonly referred to as spur gears. The gear member **14** shown in this instance is a helically-toothed gear member and, likewise, the tool member **12** shown in this instance is a helically-toothed tool member. The number of teeth on the tool member **12** is preferably not evenly divisible by the number of teeth on the gear member **14** so that the finishing action will be more suitably distributed around the gear member without producing any undesirable pattern effect on the latter.

The machine **10** is provided with a suitable base **18** upon which the machine is adapted to stand and which base is here shown as being provided with a sump or reservoir **19** adapted to hold a supply of liquid containing solid abrasive particles. The machine **10** further includes adjacent frame portions **20** and **21** rising above the base **18** and on which the tool and work spindles **11** and **13** are supported.

The sump **19** is provided in the base **18** so as to be located beneath the tool and gear members **12** and **14** for collecting the abrasive liquid which drips from these members. Suitable applicator means is provided for applying the abrasive fluid, such as a pumping means **22** located in or adjacent the sump **19** and which delivers the abrasive fluid through a delivery conduit **23** to the meshed portions of the tool and gear members **12** and **14**.

The frame portion **20** is here shown as comprising a lower bracket member **25** suitably secured to the base **18**, and an upper head **26** which is connected with the bracket member **25** for swinging and traverse movements by means of a shaft **27**. The bracket **25** has laterally-spaced hollow bearing portions **28** and **29** which support the shaft **27** for both rotative and axial movements.

The head **26** includes a pair of depending hollow yoke portions **30** and **31** which are secured on the shaft **27**, as by means of transverse pins **32**, so that the head is carried by the shaft for limited swinging about the axis of the latter and for a to-and-fro traverse movement in the general direction of the axis of this shaft. The upper portion of the head **26** is provided with a longitudinal opening **34**, through which a shaft extension **11a** of the tool spindle **11** extends and is rotatably mounted by axially-spaced antifriction bearings **35** and **36**.

The swinging movement of the head **26** about the axis of the mounting shaft **27** controls or varies the depth of tooth engagement of the teeth **12a** of the tool member **12** with the teeth **14a** of the gear member **14**. This swinging movement also permits the tool member to be engaged with, or disengaged from, the work gears which are mounted in succession on the work spindle **13**.

The closing and opening swinging movements of the head **20** toward and away from the work spindle **13** can be produced manually, as by means of a swingable actuating lever **37** and an associated toggle link **38**. The lever **37** is here shown as being a bell crank lever swingably mounted in a bracket projection **39** of the head **20** and connected with a plunger **40** by means of the toggle link **38**. The plunger **40** is slidably mounted in and extends through a bearing bracket projection **41** of the head **20** and has its free end **40a** in abutting engagement with a stop lug **42** provided on the stationary frame portion **21** at the top of the latter.

When the lever **37** is manually moved to a position in which the link **38** is substantially in alignment with the plunger **40**, the head **26** will be swung away from the frame portion **21** by the thrust of the plunger **40** against the latter, to thus disengage the teeth of the tool member **12** from the teeth of the gear member **14**. The swinging of the lever **37** in the opposite direction moves the link **38** to its tilted position shown in FIGS. 4 and 5, thereby retracting the plunger **40** and permitting a closing swinging movement of the head **26** relative to the work spindle **13** by a tension spring **43**.

The spring **43** has its opposite ends anchored respectively on the frame portion **21** and the head **26** so as to exert a pulling force on the latter for moving and holding the teeth of the tool member **12** in meshed engagement with the gear member **14**. The depth of tooth engagement of the tool member with the gear member can be controlled and varied by means of a stop and adjusting screw **44** which is threadedly mounted in the upper part of the frame portion **21** and has its inner end **44a** located so as to form a positioning stop against which the head **26** is engaged by the pulling force of the spring **43**.

Suitable driving means is provided for producing the rotative and traverse movements between the tool and gear members **12** and **14** and is here shown as comprising an electric motor **46**. In the machine **10** the rotative and traverse movements are applied to the tool member **12**, and accordingly, the motor **46** is mounted on the head **26** as by means of a bracket **47** and is operably connected with the shaft extension **11a** of the tool spindle **11**. The motor **46** is also operably connected with traverse mechanism associated with the mounting shaft **27**.

The driving motor **46** is preferably a reversible motor and is connected through suitable gearing **48** with an upright shaft **49**. The shaft **49** is mounted on the head **26** as by means of vertically spaced brackets **51** and **52** and has upper and lower driving worms **53** and **54** fixed thereon. The upper worm **53** co-operates with a worm gear **55** which is mounted on the shaft extension **11a** of the tool spindle for supplying the rotative movement to the tool member **12**.

The lower worm **54** co-operates with a worm gear **56** forming a part of the traverse mechanism and which gear is formed integral with, or rigidly secured to, a cam sleeve **57**. The cam sleeve **57** is rotatably mounted on an extension portion **27a** of the mounting shaft **27**, as by means of a pair of antifriction bearings **57a**, and is axially positioned on the shaft extension by an annular shoulder **58** of the latter and a retaining nut **59** cooperating with the inner race of the outermost one of the antifriction bearings. The cam sleeve **57** is provided with a circumferentially extending and annularly continuous cam groove **60**.

A reaction means is provided on the base **18** for cooperation with the cam sleeve **57** during the rotation of the latter and is here shown as comprising a bracket **62** supporting a roller **63** which operates in the cam groove **60**. During the rotation of the cam sleeve **57** by the operation of the driving motor **46**, the cam groove **60** reacts against the roller **63** to produce axial shifting of the mounting shaft **27** in the bearing bracket **25** to thereby cause the to-and-fro traverse movement of the tool member **12**. Since the tool spindle **11** and the cam sleeve **57** are driven by the same electric motor **46**, the to-and-fro traverse movement of the tool member **12** will occur simultaneously with the rotative movement thereof.

The gears **55** and **56** preferably are of different sizes as shown in FIG. 1, or are such that one gear has a different and odd number of teeth relative to the other, so that the finishing action on the gear member **14** will have a random distribution and the objectionable effect of a recurring pattern will be avoided.

The frame portion **21**, in addition to forming a support for the work spindle **13**, also forms a mount for the vibrator **15**. This frame portion comprises spaced upright arms **65** and **66**, of which the arm **65** forms a mount for the work spindle **13** and the arm **66** forms a mount

for the vibrator 15. The work spindle 13 includes a shaft extension 13a and the upper portion of the arm 65 is provided with a longitudinal opening into which the shaft extension 13a extends.

In the machine 10 the short-stroke vibratory movement is imparted to the gear member 14, and accordingly, the mounting of the work spindle 13 in the arm 65 is such as to permit the vibratory movement to be applied to the shaft extension 13a. For this purpose, the arm 65 is provided with a bearing sleeve 67 in which a hollow carrier sleeve 68 is slidably mounted. The shaft extension 13a of the work spindle is rotatably mounted in the carrier sleeve 68 by means of suitable antifriction bearings 69 and 70. The carrier sleeve 68 is provided at the inner end thereof with a transverse wall or cover 71 to which the vibrator 15 can be connected.

The vibrator 15 can be of any type suitable for producing the short-stroke rapid vibratory movement of a suitable vibration frequency and is here shown as being an electromagnetic vibrator having a core or magnet frame 74 and a movable armature 75 adjacent thereto. The core 74 is suitably supported by the arm 66 and is provided with a magnet coil 76 which is energizable from any suitable source of pulsating or alternating electric current of appropriate frequency.

The armature 75 is resiliently supported between vertically spaced portions 77 and 78 of the arm 66 by means of a group of plate-type springs 79. The armature 75 is here shown as comprising a body portion 75a extending in a spanning relation to the core 74 and an axial projection 80 which is connected with the cover of the carrier sleeve 68 by means of an axially rigid bar or stem 81.

The projection 80 has a transverse opening 82 through which the group of support springs 27 extends and which opening is of an axial width to accommodate any desired number of spring elements needed in the spring group 79. The upper and lower ends of the springs of the group 79 are secured with intervening spacers therebetween, to the upper and lower portions 77 and 78 of the support arm 66 as by suitable attaching screws 83. The armature 75 is connected with the intermediate portion of the spring group 79 by means of a clamping screw 84 whose head is countersunk into the armature body 75a.

The rotative movement of the work spindle 13 can be controlled during the finishing of the gear member 14 by the tool member 12 and the control means shown in this instance for this purpose is in the form of a brake device 86. The brake device 86 comprises a brake drum 87 rotatable with the shaft extension 13a and a band-type friction member 88 co-operating with such drum. The extent or force of the braking action of the band 88 on the drum 87 can be controlled or varied as by means of an adjusting screw 89.

The friction band 88 is operably connected with the arm 65 of the frame member 21 in such a manner as to prevent rotation of the friction band with the drum 87 but to still permit the short-stroke rapid axial vibratory movement of the work spindle 13. This is accomplished by providing the friction band 88 with a lug projection 90 which is slidably received between a pair of rigid stop lugs 91 and 92 provided on the arm 65. The slot or space between the lugs 91 and 92 is open on the side of the arm 65 facing the gear member 14, or is of a greater axial width than the lug projection 90, so as to permit the above-mentioned short-stroke axial vibratory movement of the work spindle 13.

During the operation of the machine 10, rotational movement and a to-and-fro traverse movement are imparted to the tool member 12 by the operation of the electric motor 46 and this will result in the gear 14 being rotatably driven by the tool member assuming, of course, that the setting of the brake device 86 permits such rotation of the gear. When the tool member 12 comprises nylon or other wear-resistant plastic material as mentioned above, the abrasive action between the tool member and the gear 14 is obtained by supplying the abrasive fluid to the tool member, such as through the pipe 23 to the point of meshed engagement. Since nylon is highly resistant to wear, the tool member 12 will co-operate effectively with the gear member for producing the desired abrasive finishing action on the latter without itself being subject to any rapid deterioration.

The nylon of the tool member 12 also gives this member a somewhat yieldable characteristic which enables it to be indented by and pick up solid abrasive particles from the fluid being supplied, in such a manner that the particles become temporarily attached to or imbedded in the tool member. The embedded abrasive particles are yieldably held by the plastic material and are highly effective on the gear member for producing the desired finishing action thereon and, since the embedded particles are continuously being renewed, any wear on the tool member itself will be of a small or minimum amount.

FIG. 8 of the drawings shows the meshed engagement of the tool member 12 with the gear member 14 and represents a new or unworn condition of the tool member. This view of the drawings also represents the rest condition of the machine 10 when the tool member has been initially moved into mesh with the gear member but prior to the starting of the drive motor 46. At this time a small clearance space 93 preferably exists between the adjacent faces of the meshed teeth 12a and 14a, as shown in FIG. 8.

When the machine 10 is put into operation, the direction of rotation of the drive motor 46 will determine which side face of the teeth of the gear member 14 will be finished by the tool member 12. FIG. 9 illustrates the co-operation of the tool member 12 with the gear member 14 and the resulting finishing operation on the tooth faces 94 when the rotation is in the direction indicated by the arrows 95 of this view. Finishing of the opposite tooth faces 96 of the gear member 14 is accomplished by operating the machine 10 with the driving motor 46 rotating in the opposite direction as is indicated by the arrows 97 of FIG. 10.

The co-operation of the tool member 12 with the gear member 14 in a manner to finish both faces of the teeth in the manner just described in connection with FIGS. 9 and 10, results from the control provided by the brake device 86 for the work spindle 13. Thus, when the brake 86 retards the rotation of the work spindle while the latter is being rotated in one direction, the tool member will co-operate with the tooth faces 94 of the gear member and when the direction of drive of the motor 46 is reversed, the drag of the brake will cause the tool member to finish the opposite faces 96 of the gear teeth.

The holding force or drag acting on the gear member 14 during the finishing thereof by the tool member 12 can be varied by adjusting the screw 89 to suitably change the energization or effectiveness of the brake device 86. If desired, the machine 10 can be operated with the brake device 86 de-energized and, in that case, the inertia of the gear member 14 and of the rotative parts associated therewith will provide the retarding action or drag for causing one or the other of the tooth faces of the gear member to be abradingly acted upon by the tool member.

FIG. 12 of the drawings illustrates a somewhat worn condition of the tool member 12 and which worn condition is apparent from the showing of the relatively reduced circumferential thickness of the teeth 12a. Since the machine 10 is capable of producing the desired finishing action alternately on both sides of the teeth of the gear member 14, the worn condition of the tool member 12 can be tolerated and hence a given tool member can be used for a prolonged period of time for economical operation.

Engagement of the tool member 12 with the gear

member 14 with an initial space 93 between the meshed teeth, as shown in FIG. 8, is obtainable by the setting or in-and-out control provided by the screw 44 and is usually desirable in the operation of the machine 10 because the tool member will then operate in the manner explained above in connection with FIGS. 9 and 10 and will have the long life referred to in connection with FIG. 12. If desired, however, the screw 44 can be so set that the teeth of the tool member 12 will initially be in contact with the teeth of the gear member 14, that is, without any intervening space 93. Under these circumstances the tool member 12 will operate simultaneously on and finish both side faces of the meshed teeth of the gear 14.

FIG. 11 of the drawings shows a gear-shaped tool member 99 which can be used in the same manner as the tool member 12 for the abrasive finishing of the gear member 14 but which is of a modified form and comprises a molded or formed member 99a made of ceramic, plastic or composition material and having abrasive particles 100 embodied in and distributed through this member. In the operation of the machine 10 when using the modified form of tool member 99, the supply of abrasive fluid through the pipe 23 is discontinued, although a coolant or flushing fluid can still be applied, if desired. FIG. 12 of the drawings is also illustrative of a worn condition of the tool member 99.

During the finishing of gears by the apparatus and method of this invention, the application of the short-stroke rapid vibratory movement to one or the other of the gear-shaped tool and work gear members is highly advantageous and results in a more rapid cutting or abrading operation on the gear and in a more satisfactory finish on the tooth faces. These advantageous results are achieved from the vibratory action, regardless of whether the gear-shaped tool member being used is one for carrying out a shaving or burnishing operation on an unhardened gear; or is one for carrying out an abrading operation on a hardened gear, such as the nylon tool member for a wet abrading operation or the molded abrasive tool member of FIG. 11 for a dry abrading operation.

In making use of the vibratory movement during the operation of the machine 10, for the abrasive finishing of the gear member 14 by the use of a tool member 12 comprising nylon, the gear member is subjected to the short-stroke rapid vibratory movement during the time that the rotative and relative traverse movements are taking place between the tool and gear members. This vibratory movement is imparted to the gear member 14 in the general direction of the rotation axis of the work spindle 13 by the above-described vibrator 15.

If desired the machine 10, when using the nylon tool member 12 in abrasive rotative and traverse co-operation with the gear member 14, can be operated without use of the vibratory movement supplied by the vibrator 15. This can be accomplished by operating the machine 10 with the vibrator 15 in a de-energized or idle condition. The advantages and improved results obtainable from the use of the nylon tool member 12 can thus be achieved independently of and separately from the advantages obtainable from the application of the short-stroke rapid vibratory movement supplied by the vibrator 15.

When the tool member 12 and the gear member 14 are of the helically toothed shape shown in the drawings and mentioned above, an axial vibratory movement being supplied by the vibrator 15 while rotation of the gear member is being retarded by a holding action or drag, provided either by the brake device 86 or by inertia, will result in a to-and-fro axial corkscrew movement of the gear member and this corkscrew movement will increase the effectiveness of the finishing operation being performed. While the corkscrew movement just described is taking place, the gear member is being rotated by the tool member 12 and the tool member is also being moved back and forth by the axial traverse movement being imparted thereto. The to-and-fro corkscrew movement is thus superimposed on the rotative movement, or rotative and traverse movements, with the result that the finishing action of the corkscrew movement will be distributed around and across the gear member by the rotative and traverse movements.

In the earlier portion of this specification, use of the novel method for gear finishing with the tool member and gear member in a crossed-axes relation, was referred to. This use of the method is desirable particularly for finishing helically-toothed gear members and is obtainable in the modified forms of finishing machines 102 and 103 shown in FIGS. 13 and 14, respectively, of the drawings.

In the modified machine 102 of the FIG. 13, the head 104 supporting the tool member 12 comprises two relatively adjustable frame members 105 and 106. The frame member 105 has the tool spindle 11 rotatably mounted therein and the frame member 106 is connected with the mounting shaft 27 in the same manner as has been described above for the head 26 of the machine 10.

Two reversible electric driving motors 108 and 109 are provided in the modified machine 102, of which the motor 108 is used to rotate the tool member 12, and the motor 109 is used to produce the to-and-fro traverse movement of the tool member through traverse mechanism which includes the cam sleeve 57. The motor 108 is mounted on the frame member 105 by a suitable bracket 110 and has a worm or the like in driving engagement with the gear 55. The motor 109 is mounted on the frame member 106 by a suitable bracket 111 and has a worm or the like in driving engagement with the gear 56.

The frame member 105 is adjustably movable relative to the frame member 106 by a rocking movement permitted by cooperating lugs and bearing surfaces 113 and 114 carried respectively by the frame members 105 and 106. The adjusting means also includes clamping screws 115 extending through slots provided in the lugs 113 and having threaded engagement in the frame member 106. In other respects, the modified machine 102 is substantially the same as the machine 10 and includes the vibrator 15 and the brake device 86.

From the construction just described for the modified machine 102, it will be seen that the adjustable connection provided between the frame members 105 and 106 will permit the frame member 105 to be rocked relative to the frame member 106 to locate the rotation axis of the tool spindle 11 in a tilted or crossed relation to the rotation axis of the gear member 14. When the tool member 11 has been thus located in a crossed-axes relation to the work spindle 13, the clamping screws 115 are tightened and the machine 102 is then in a condition for carrying out any and all of the gear finishing procedures explaied herein for the machine 10.

The electric motors 108 and 109 are preferably induction motors so that, even though they may be of the same rating, they will operate at somewhat different speeds because of the different work loads to which they will be subjected. The different load speeds of the motors 108 and 109 will therefore produce a variable and better distributed resultant action during the finishing of the gear member 14 and any tendency to produce an undesirable pattern effect on the latter will be avoided.

The modified machine 103 shown in FIG. 14 also provides for tilting of the tool spindle to a crossed-axes relation relative to the work spindle and this is accomplished by a rocking of the head and bracket members 116 and 117 relative to a support bracket 118. In this modified machine 103, the rockable adjustment just referred to is obtainable by providing the bracket member 118 with curved bearing surfaces 119 on which lug portions 120 of the bearing bracket 117 are relatively slidable. When the desired crossed-axes position of adjustment for the tool spindle 11 has been obtained, the lug portions 120 are secured in a fixed relation against the curved bearing surfaces 119 by suitable clamping screws 121 extending

through the lug portions and having threaded engagement in the bracket member 118.

The modified machine 103 requires only one driving motor 46a for supplying both the rotative and transverse movements of the tool member 12. The motor 46a is mounted on the head 26a as by means of a suitable mounting bracket 47a. In all other respects the modified machine 103 is the same as the machine 10 and includes the vibrator 15 and the brake device 86, and is operable to carry out all of the gear finishing procedures explained herein for the machine 10.

Instead of applying abrasive fluid to the tool and gear members 12 and 14 by means of a pump and delivery pipe, such as the pump 22 and the pipe 23 of the machine 10, the abrasive fluid can be applied to one of the meshed members by an applicator wheel as shown in the modified finishing machine 123 of FIG. 15. In this modified machine, the base 18 is provided with a sump or reservoir 19 containing a body of abrasive liquid 124 and a rotatable applicator wheel 125 is partially immersed in the abrasive fluid and has running contact with the periphery of the tool member 12.

The applicator wheel 125 is preferably a gear-shaped member or pickup wheel which is rotatably mounted on the base 18 as by means of a pivot shaft 126. As shown in FIG. 15, the applicator wheel 125 is driven by the tool member 12 and operates to pick up abrasive fluid from the sump 19 and apply the fluid directly to the tool member. The applicator wheel 125 can be made of any suitable material but is preferably absorbent or porous in character to increase the effectiveness thereof in picking up the abrasive liquid and applying the same to the tool member.

If desired, the machine 123 can also be provided with one or more gear-shaped distributor wheels 127, in this case two such wheels, located on opposite sides of the applicator wheel 125 and in meshed engagement with the tool member 12. The wheels 127 are preferably of an absorbent material, such as felt, and act to distribute the abrasive fluid evenly on the tool member as well as to remove excess fluid therefrom.

FIGS. 16 and 17 of the drawings show a modified construction by which any one of the machines 10, 102, 103 and 123 can be adapted for a finishing operation on a gear member comprising a plurality of axially adjacent gear elements. A gear member 14 of this form is shown in FIG. 16 and comprises two axially adjacent helically-toothed gear elements 129 and 130 in either a stacked or joined relation to each other, and which gear member is mounted on a rotatable work spindle 13.

The gear-shaped tool member 12 of FIGS. 16 and 17 comprises axially adjacent helically-toothed tool elements 132, 133 carried by the tool spindle 11. The tool elements 132 and 133 are relatively rotatably adjustable in opposite directions so that when these tool elements are in meshed engagement with the gear elements 129 and 130, they will act on the adjacent side faces of the teeth of the two gear elements when the tool elements are rotatably adjusted in one direction and will act on the remote side faces of the teeth of the two gear elements when the tool elements are rotatably adjusted in the opposite direction.

The relative adjusting movement between the tool elements 132 and 133 is obtained by means of a pivoted adjusting shaft 135 carried by the tool element 132 and having an offset eccentric portion or crank element 136 engaged in a radial slot 137 provided in the tool element 133. Pivotal movement imparted to the adjusting shaft 135 causes the crank element 136 to exert a camming force on a side wall of the slot 137 to thereby produce rotative adjusting movement between the tool elements 132 and 133 in accordance with the direction of the pivotal movement imparted to the adjusting shaft.

The pivot shaft 135 can be moved to its adjusting positions as by means of an actuating handle 138 in the form of a bent pin having a portion thereof extending transversely through the head 139 of the pivot shaft. The two adjusting positions to which the handle 138 is movable are illustrated in FIG. 7, one being a phantom line position 138a and the other being shown in full lines. The handle 138 can be retained in either of these adjusting positions as by means of a fork-like clip 140 engageable with a holding screw 141 and a compression spring 142 interposed between the clip and the handle.

The modified tool member 12 of FIGS. 16 and 17 can be used in any of the machines 10, 102, 103 and 123 for finishing plural gear elements 129 and 130 in accordance with any of the finishing procedures described herein for those machines.

The gear-shaped tool member 12 comprising nylon and the abrasive-carrying tool member 99 of FIG. 11, when used for carrying out the abrading gear finishing procedures described hereinabove, can also be referred to as a lap or by the terms lap member or lap wheel.

From the accompanying drawings and the foregoing detailed description it will now be readily understood that this invention has provided a novel method and gear finishing machines by which a rotative and relative traversing movement is produced between meshed tool and gear members for finishing the side faces of the gear teeth. The various features of the machines and method and the operational advantages and improved results derived therefrom having already been described in the foregoing specification, they need not be repeated or further summarized.

Although the gear finishing method and apparatus of this invention have been illustrated and described herein to a somewhat detailed extent, it will be understood, of course, that this invention is not to be regarded as being limited correspondingly in scope but includes all changes and modifications coming within the terms of the claims hereof.

Having described my invention, I claim:

1. In a method of finishing a work member comprising a group of axially adjacent gear elements the steps of providing a rotatable tool member comprising axially adjacent relatively rotatably adjustable gear-shaped tool elements, placing said tool member with the tool elements thereof in mesh with the respective gear elements of said group, producing an adjusting rotative movement in one direction between said tool elements, rotating said tool member and work member in such meshed engagement, producing an abrading condition between the meshed portions of said tool member and work member during the meshed rotation of said members, vibrating at least one of said members with a rapid short-stroke generally axial vibratory movement while the meshed abrading rotative movement is taking place between said members, producing an adjusting rotative movement in the opposite direction between said tool elements, and continuing the vibratory movement of said one member and the meshed abrasive rotation of said members.

2. In apparatus for finishing a gear member comprising a pair of axially adjacent gear elements, a tool member comprising axially adjacent relatively rotatably adjustable gear-shaped tool elements, means supporting said tool member for rotation, drive means operable to rotate said tool member, means supporting said gear elements for rotative meshed engagement with the respective tool elements, means for producing an abrading action of said tool elements on said gear elements, and adjusting means effective between said tool elements for producing an adjusting relative rotary movement therebetween for circumferentially pressing the tool elements against the side faces of the gear teeth.

References Cited in the file of this patent

UNITED STATES PATENTS

605,283 Holland ---------- June 7, 1898

(Other references on following page)

11

UNITED STATES PATENTS

787,405	Schrader	Apr. 18, 1905
1,917,178	Wolfe	July 4, 1933
1,948,071	Hofmann et al.	Feb. 20, 1934
2,044,442	Offenbacher	June 16, 1936
2,121,479	Drummond	June 21, 1938
2,136,266	Reinecker	Nov. 8, 1938
2,351,842	Seibold	June 20, 1944
2,385,129	Davis	Sept. 18, 1945
2,443,410	Wickman	June 15, 1948

12

2,658,259	Aldino et al.	Nov. 10, 1953
2,913,858	Praeg et al.	Nov. 24, 1959

FOREIGN PATENTS

391,058	Great Britain	Apr. 20, 1933
800,680	Great Britain	Aug. 27, 1958

OTHER REFERENCES

Publication: "Machine Design," March 1954, pp. 153 and 154.