United States Patent

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[33] **Japan**
[31] **43/58688**

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[54] **GRINDING DEVICE**
10 Claims, 12 Drawing Figs.

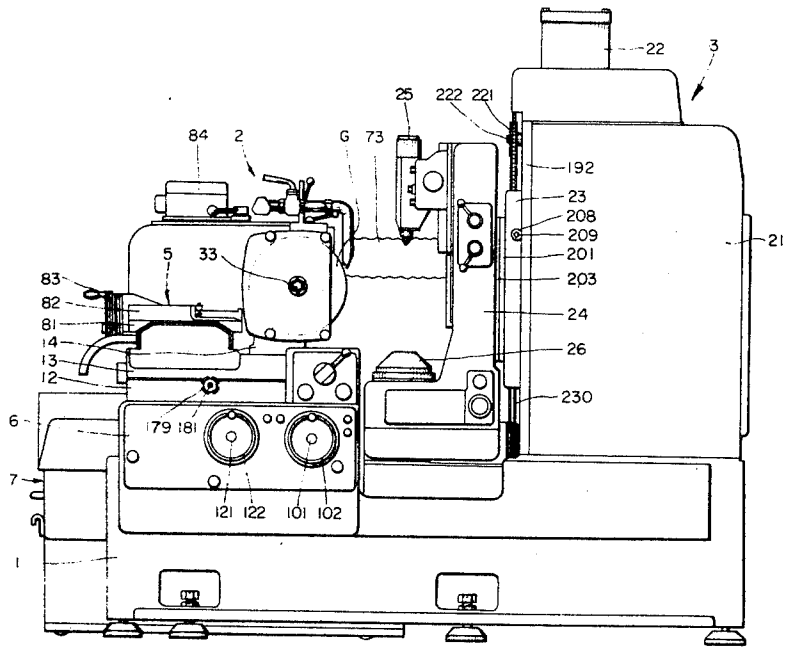
[52] **U.S. Cl.** **51/95**
[51] **Int. Cl.** **B24b 3/34**
[50] **Field of Search** ..... 51/94, 95, 95 GH, 105

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Primary Examiner—Othell M. Simpson
Attorney—Waters, Roditi, Schwartz & Nissen

ABSTRACT: A gear grinder having a prime mover to drive both a grindstone and a work to be ground in synchronism with each other. The gear grinder has a power transmission means to deliver output from the prime mover to both the work and the grindstone for moving them, which transmission means includes a uniform universal joint having a spur gear slidably engaging a pinion located on power receiving side. The spur gear slides along said pinion as one of the work and the grindstone moves relative to the other.



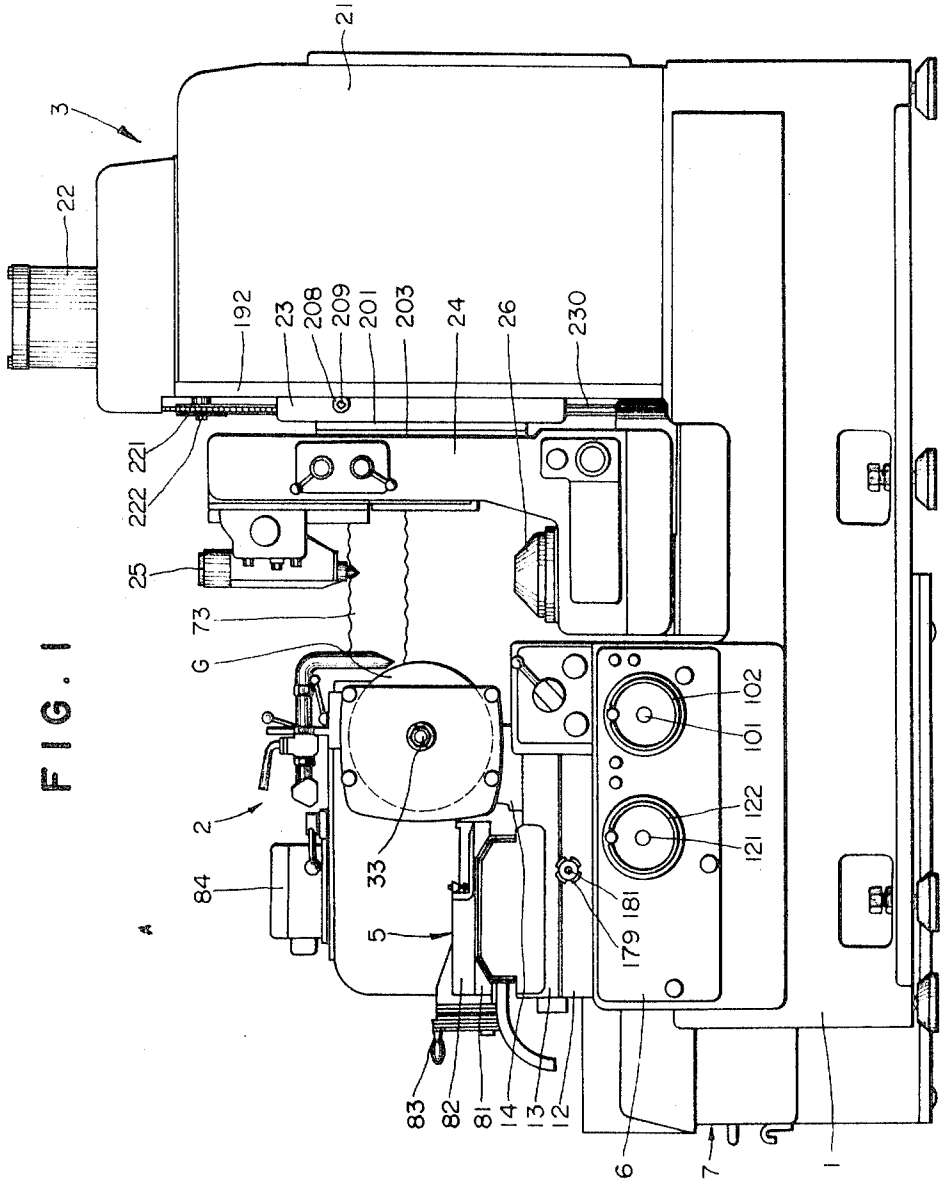

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FIG. 1

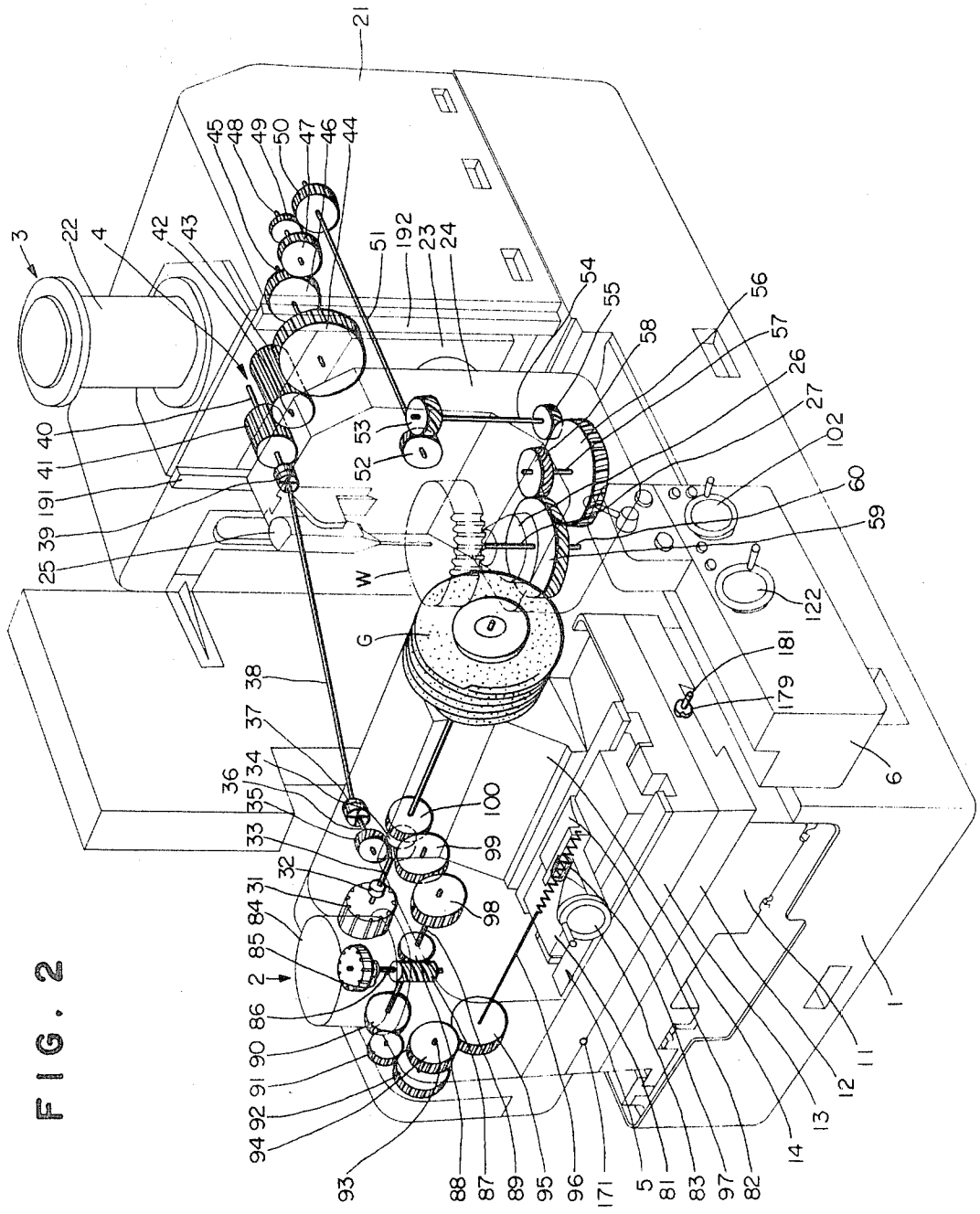

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FIG. 2

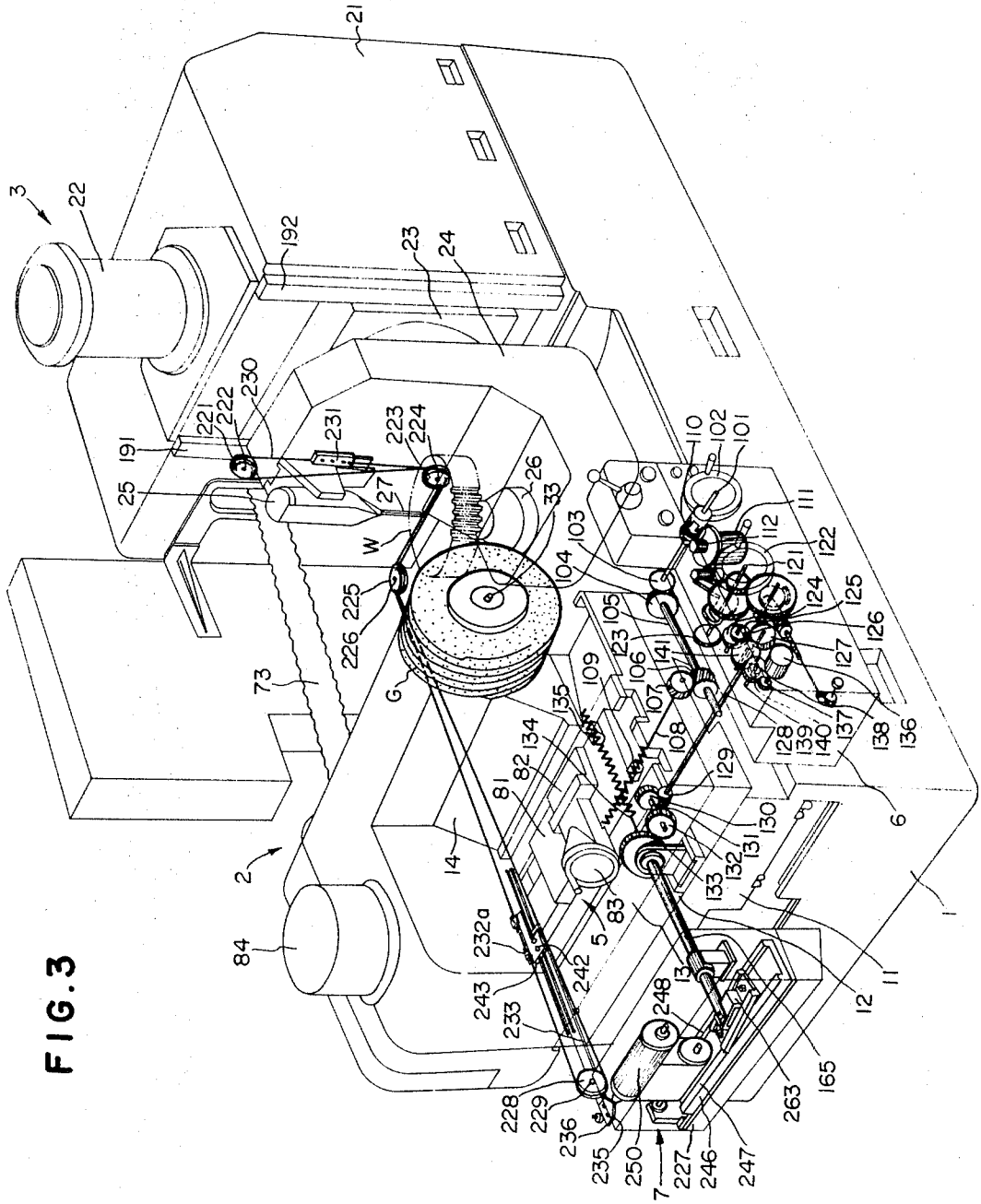

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FIG. 3

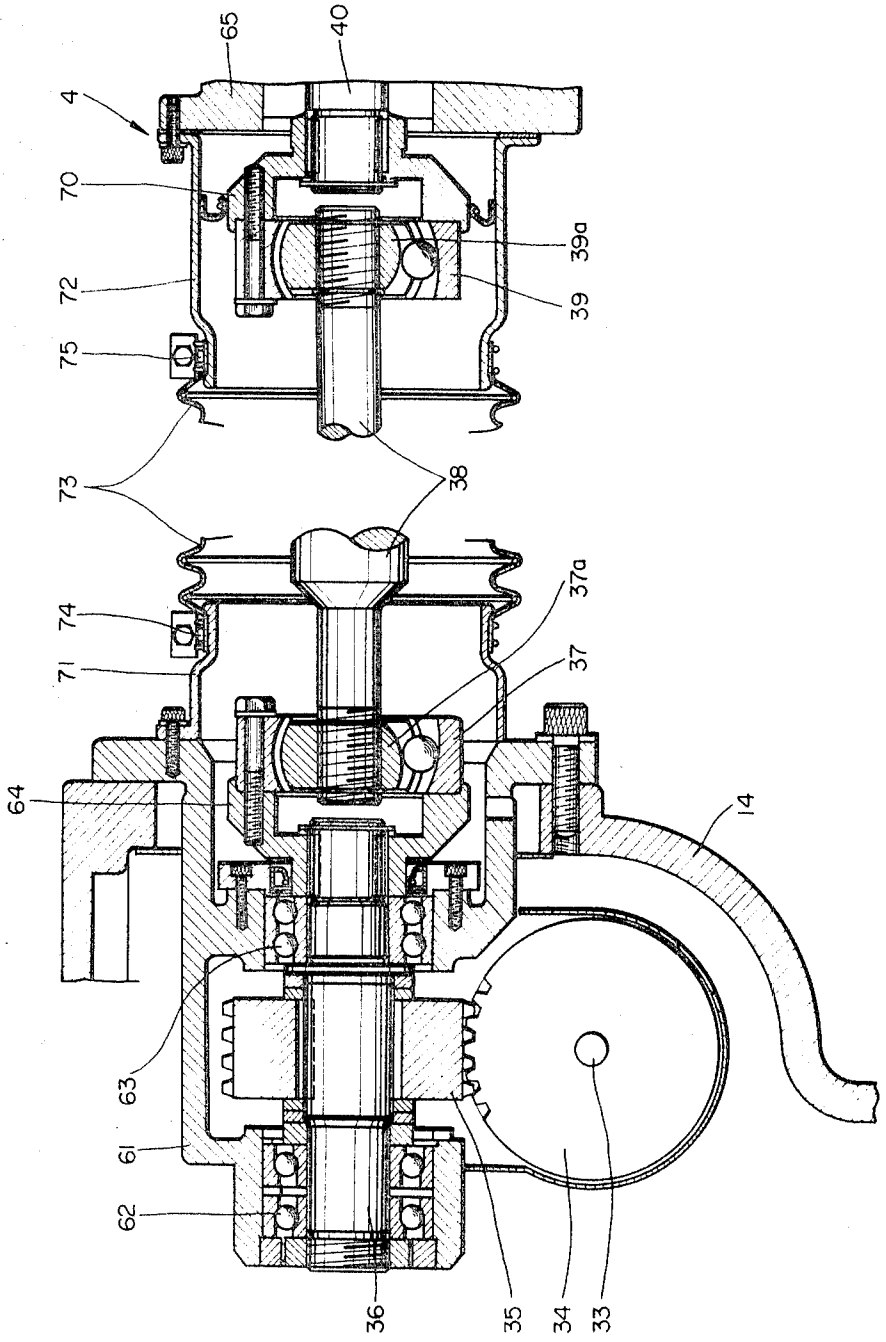


FIG. 4

FIG. 5

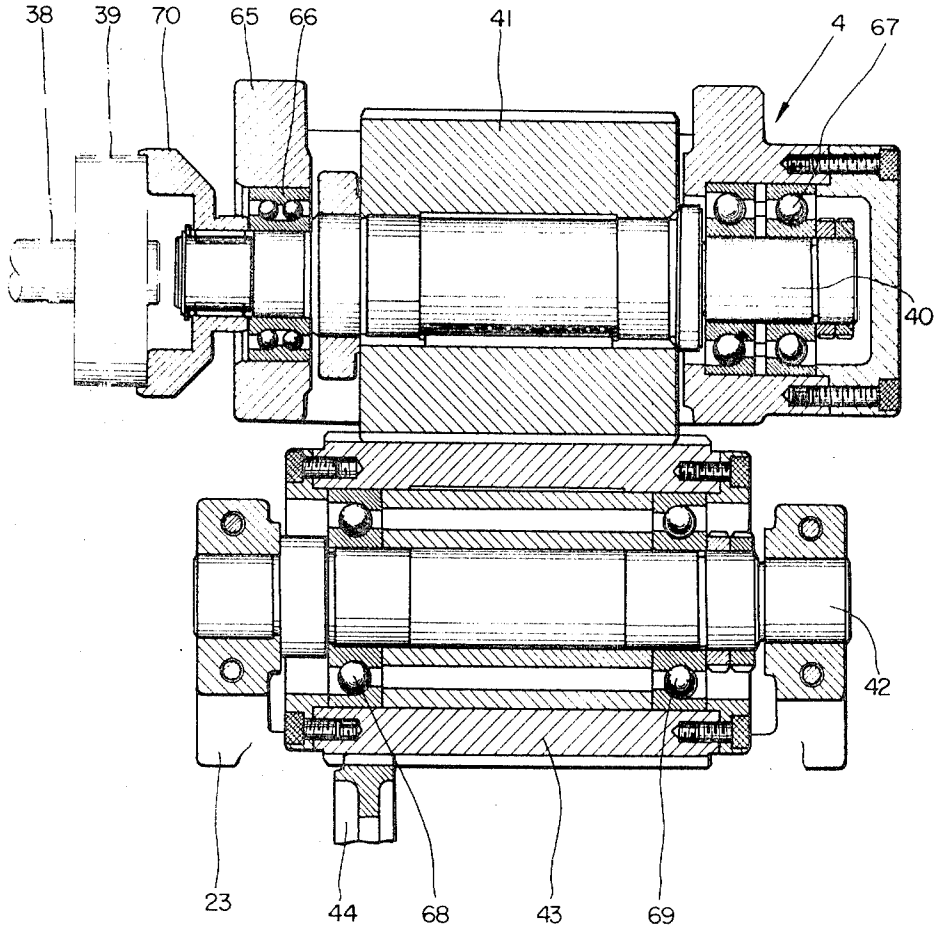


FIG. 6

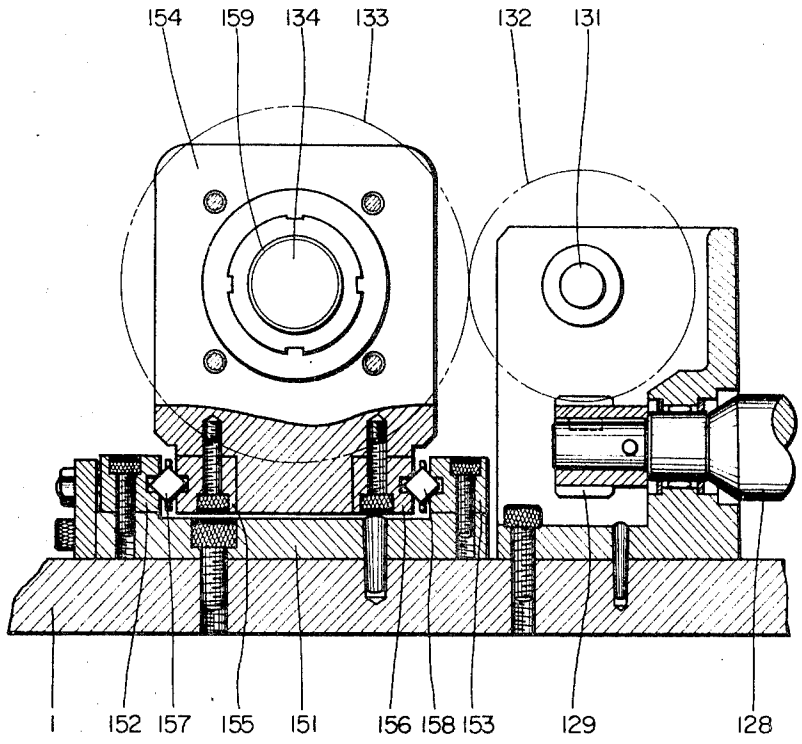


FIG. 7

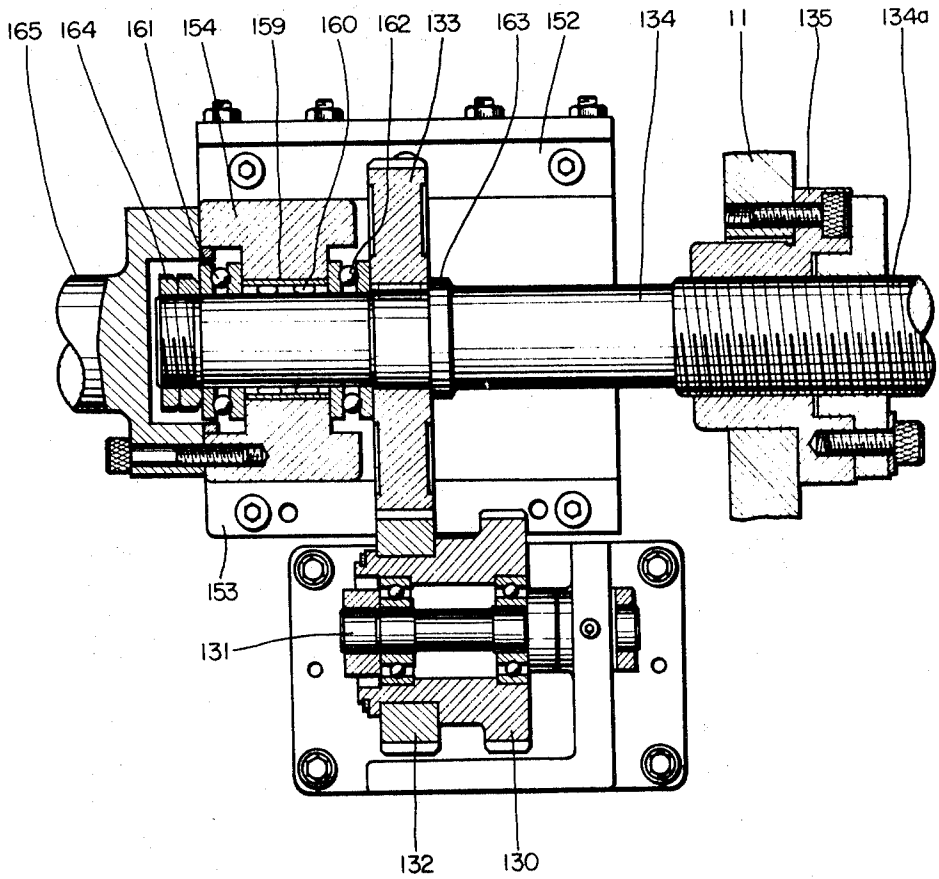

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FIG. 8

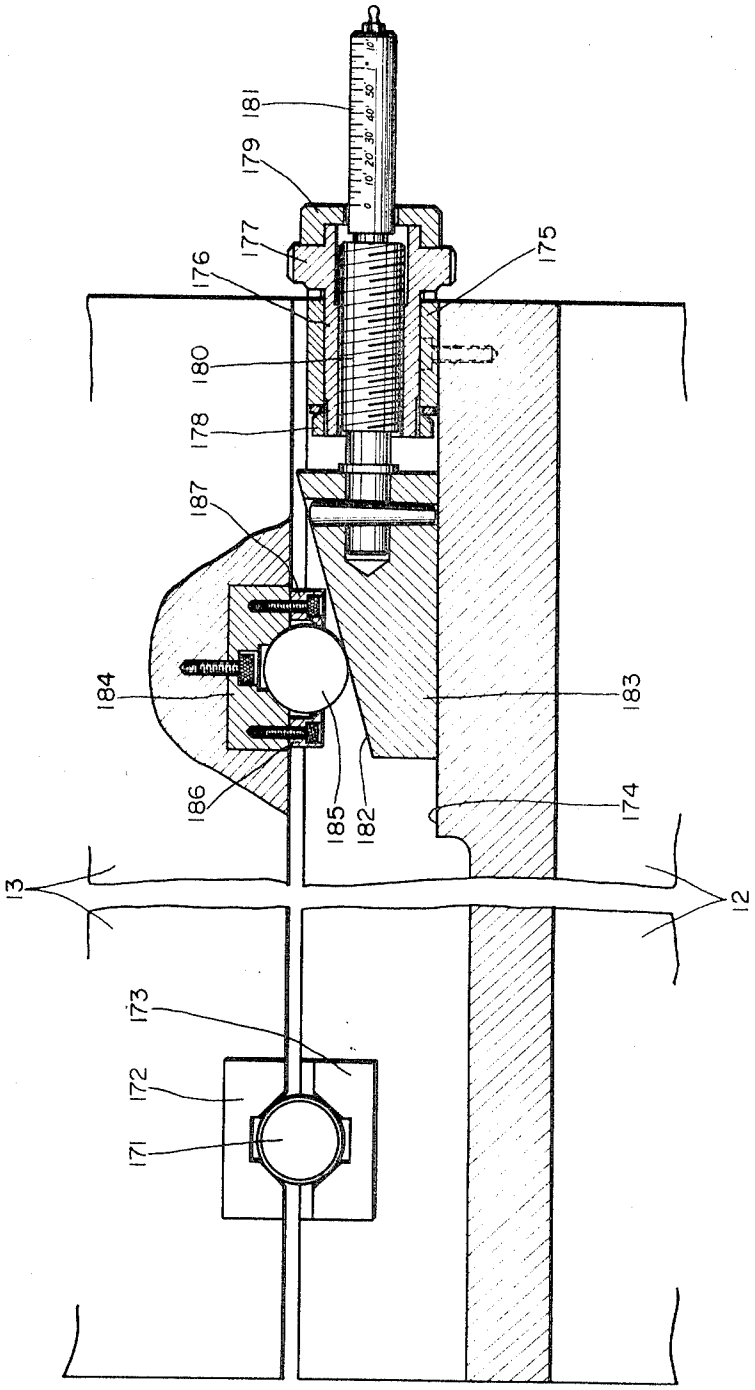

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FIG. 9

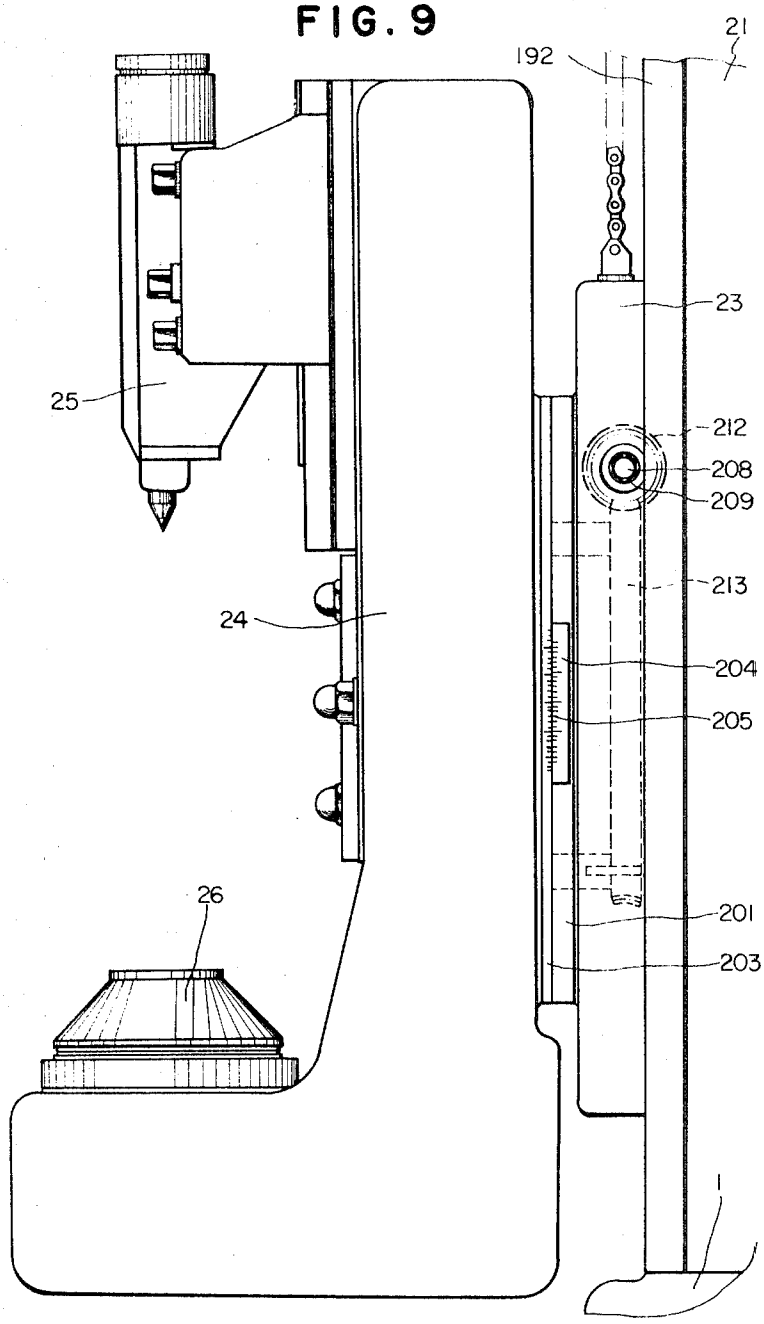
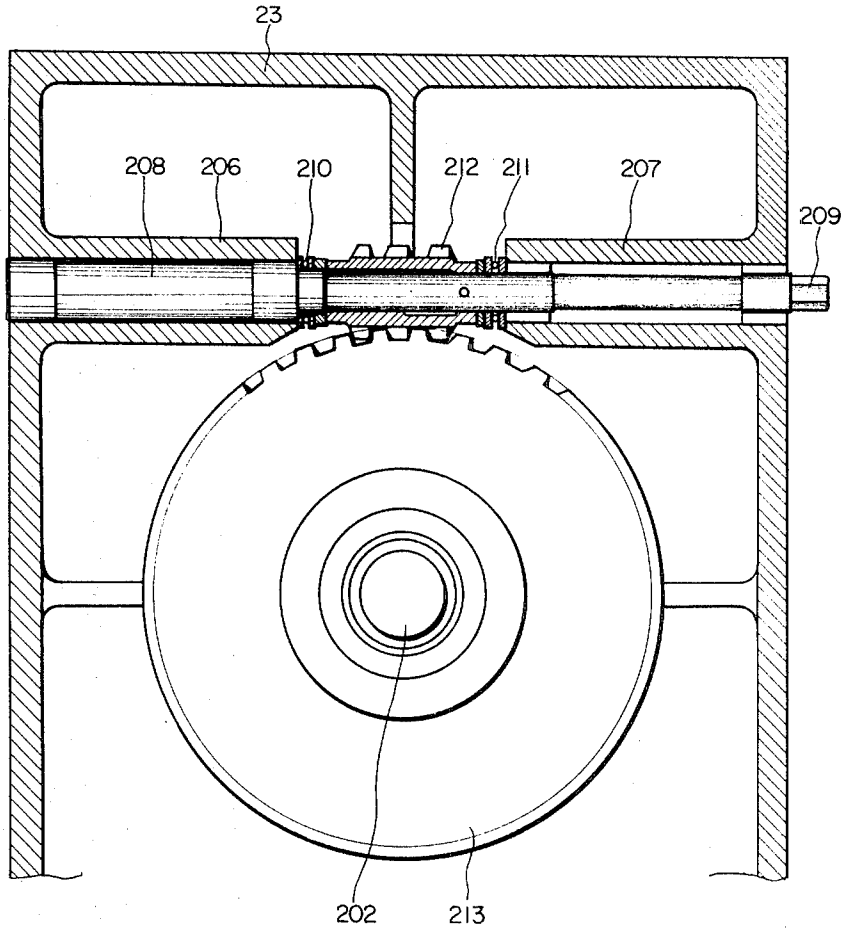


FIG. 10



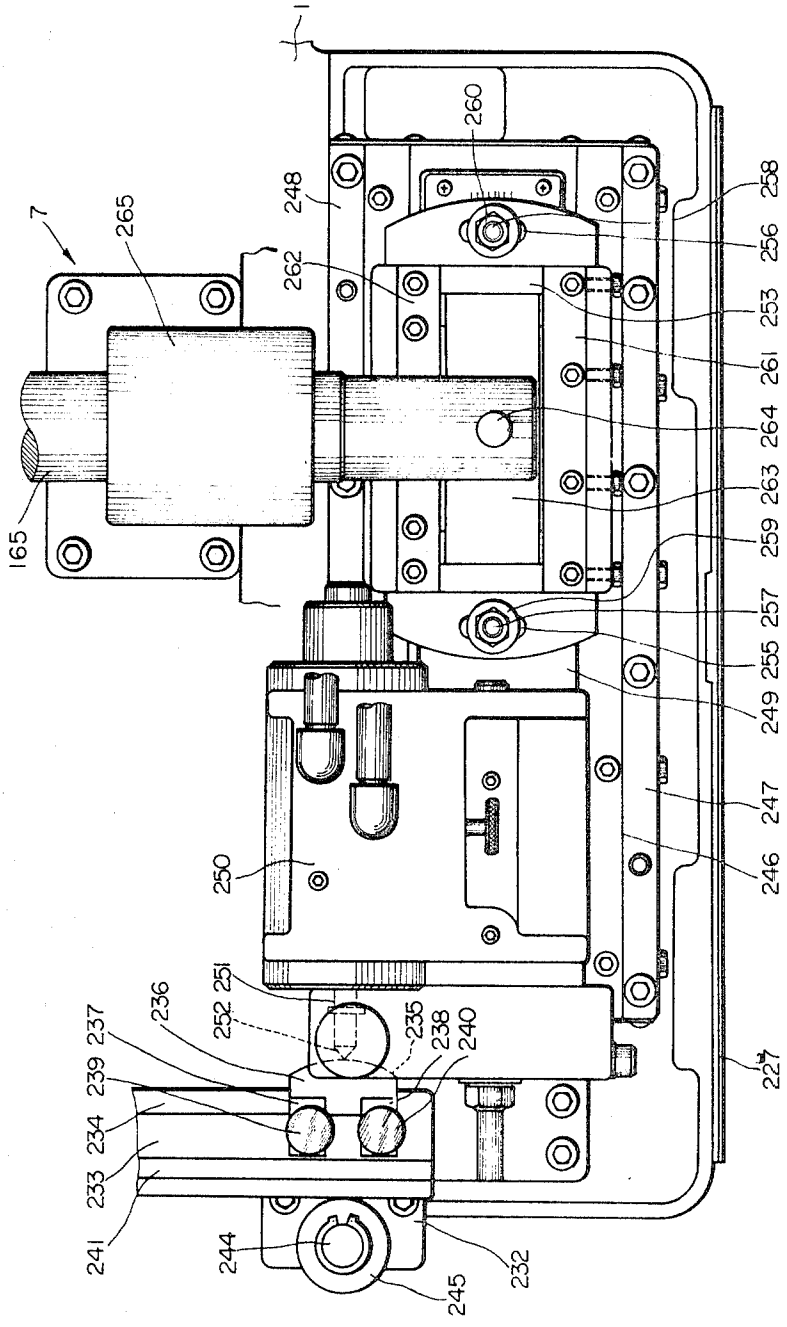
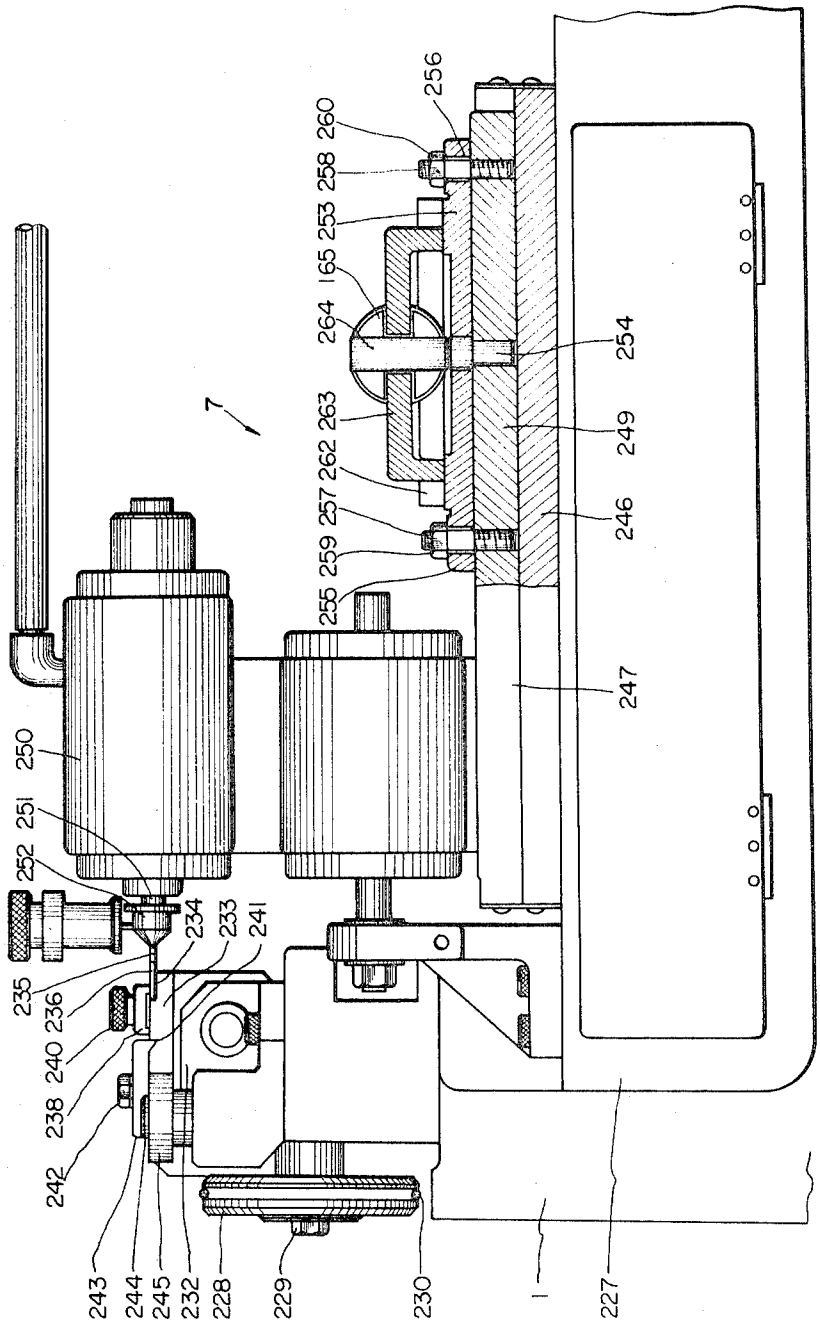

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FIG. 11

FIG. 12


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GRINDING DEVICE

This invention relates to a grinding device, and more particularly to a gear grinder of simple construction in which a work and a grinding wheel are driven by a single driving prime mover with high accuracy by using rigid driving mechanism without using any spline shafts and worm gears.

Generally speaking, high accuracy and high efficiency are required as essential features in grinding devices, especially in gear grinders. From the viewpoint of achieving high accuracy, it is preferable to make driving mechanism, as simple as possible, which mechanism drives a grinding wheel and a work, because the more complicated the driving mechanism is, the lower the rigidity of the driving mechanism will be, and the low rigidity results in a reduced accuracy. From the viewpoint of achieving high efficiency, the grinding means should be adjustable for different conditions of the grinding wheel and the work, i.e. it should be easily adjustable.

In a known gear grinder, an electric motor drives both a work and a grinding wheel in synchronism with each other by using a driving mechanism. For instance, continuous gear generation is carried out by using a hob-shape grinding wheel formed in a rack-type thread, while producing generating movement on both the grinding wheel and the work. However, such known gear grinder has disadvantages in that a number of slidable spline shafts are used in its driving mechanism together with worm gears in its final speed reduction means, for the purpose of providing controllability for various operative conditions, which spline shafts and worms result in a comparatively low rigidity of the driving mechanism and a reduced overall accuracy.

In another known gear grinder, two synchronous motors are used for driving a grinding wheel and a work separately yet in synchronism with each other so as to carry out continuous gear generation. This type of gear grinder can prevent the reduction in the rigidity of the driving mechanism by driving the grinding wheel and the work separately with separate synchronous motors, respectively. However, with the two synchronous motors, the control mechanism for driving them in synchronism becomes complicated, and its starting operation becomes complicated. In addition, the gear grinder has disadvantage in that its accuracy is reduced as the grinding resistance of the work varies during grinding operation, and that it is not suitable for generating accurate gear teeth on segment-shaped gear wheels.

Therefore, an object of the present invention is to provide a new gear grinder which obviates the aforesaid difficulties of known gear grinders.

Another object of the present invention is to provide a gear grinder easily adjustable for different conditions of grinding wheels and works, so as to provide a high production efficiency.

It is another object of the invention to provide a gear grinder in which a highly stable accuracy can be ensured during fine adjustment to meet different conditions of the grinding wheel and the work.

A further object of the present invention is to provide a gear grinder capable of efficiently producing various spur gears, helical gears, and the like, and also capable of heavy grinding operation.

According to the present invention, there is provided a gear grinder comprising a base, a grinding wheel head holding a grinding wheel and movably mounted on said base, a worktable holding a work and movably mounted on said base, a driving prime mover, an operating mechanism to operate both said grinding wheel and said work, a power transmission means including at least one constant velocity universal joint to deliver output from said prime mover to said operating mechanism, and a crowning mechanism to be actuated in response to vertical movement of said work, said constant velocity universal joint transmitting power between said grinding wheel and said work and consisting of a spur gear slidably engaging a pinion located on power receiving side, said spur gear sliding along said pinion as one of worktable and said grinding wheel head moves relative to the other.

Other objects and a fuller understanding of the present invention may be had referring to the following description and claims, taken in conjunction with the accompanying drawings, in which;

FIG. 1 is a side view of a gear grinder according to the present invention;

FIG. 2 is a schematic perspective view of a driving mechanism to drive a grinding wheel and a work in the gear grinder of FIG. 1;

FIG. 3 is a schematic perspective view of a shifting mechanism of the grinding wheel, a grinding wheel in feed mechanism, and a crowning mechanism;

FIG. 4 is a vertical sectional view of a constant velocity universal joint usable in a driving mechanism of the grinding wheel and the work;

FIG. 5 is a horizontal sectional view of a slidable spur gear means in the driving mechanism of the grinding wheel and the work;

FIG. 6 is a vertical sectional view of a grinding wheel head driving mechanism in the grinding wheel in feed mechanism;

FIG. 7 is a horizontal sectional view of the mechanism of FIG. 6;

FIG. 8 is a vertical sectional view of a means for regulating for lead angle of the grinding wheel;

FIG. 9 is an elevation of a means for regulating for helix angle of the work;

FIG. 10 is a vertical sectional view of the means of FIG. 9;

FIG. 11 is a plan view of the crowning mechanism; and

FIG. 12 is an elevation of the crowning mechanism of FIG. 11, with a part cut away.

Like parts and members are designated by like numerals and symbols throughout the drawings.

Referring to FIGS. 1 to 3, illustrating the overall construction of a gear grinder according to the present invention, a base 1 supports a grinding wheel actuating mechanism 2 mounted on its one end, and a work actuating mechanism 3 is disposed at its opposite end.

The grinding wheel actuating mechanism 2 consists of a grinding wheel head base 11 reciprocative in the longitudinal direction of the base 1, a grinding wheel head lower board 12 mounted on the grinding wheel head base 11 so as to be reciprocative at a right angle to the longitudinal direction of the base 1, a grinding wheel head upper board 13 mounted on the grinding wheel head lower board 12 so as to be laterally swingable, and a grinding wheel head 14 secured to the grinding wheel head upper board 13. A hob-shape grinding wheel G, which is formed like a rack-type screw, is replaceably attached to the grinding wheel head 14.

The work actuating mechanism 3 consists of a column 21 mounted on the base 1, a hydraulic cylinder means 22 mounted within the column 21, a vertically reciprocating plate 23 connected to the hydraulic cylinder means 22 and disposed on that side of the column 21 which faces the grinding wheel G, and a worktable 24 pivotally secured to one side of the vertically reciprocating plate 23. The worktable 24 has a pair of arbor holders 25 and 26 secured to the upper end and the lower end thereof, respectively, so as to replaceably hold the upper end and the lower end of an arbor 27 carrying work W, or a gear to be ground. The work W is secured to the middle point of the arbor 27 or to the proximity thereof. For simplicity, the details of the arbor holders 25 and 26 are not shown, but it is well-known in the art to construct them so that the lower arbor holder 26 opens and closes as the upper arbor holder 25 moves upwards and downwards, respectively. The arbor 27 can be secured to the arbor holders by hydraulic chucks at any position so as to keep the work W engageable with the grinding wheel G.

The grinding wheel actuating mechanism 2 further includes a shifting means to feed the grinding wheel G in its axial direction, a grinding wheel in feed means to feed the grinding wheel G in the radial direction of the work W, and a lead angle

regulating mechanism to incline the grinding wheel G. The work actuating mechanism 3 includes a feeding means to vertically reciprocate the work W along its tooth trace, and a helix angle regulating means for inclining the work W along the helix angle thereof.

The grinding wheel actuating mechanism 2 and the work actuating mechanism 3 are connected to a driving mechanism 4 for driving the grinding wheel G and the work W. A grinding wheel truing mechanism 5 is attached to the grinding wheel actuating mechanism 2. An operating panel 6 is mounted on one sidewall of the base 1, while a crowning mechanism 7 is mounted on another side of the base 1.

The driving mechanism 4 for driving the grinding wheel G and the work W will now be described in detail referring to FIG. 2. A motor 31 is mounted in the grinding wheel head 14, and one end of a grinding wheel spindle 33 is connected to the motor 31 with a coupling 32. The grinding wheel G is of screwlike hob shape and coaxially secured to the opposite end of the grinding wheel spindle 33. The grinding wheel G is directly driven by the motor 31 through the coupling 32 and the grinding wheel spindle 33.

A gear 34 is secured to the grinding wheel spindle 33 at an intermediate portion thereof, and the gear 34 meshes with another gear 35 at a right angle thereto. The gear 35 is connected to a constant velocity universal joint 37 through a shaft 36, so as to deliver the motor output power toward the Work W. A connecting rod 38, which is preferably hollow, is secured to the constant velocity universal joint 37 at one end thereof, while the opposite end of the rod 38 is connected to another constant velocity universal joint 39 located in the proximity of the work G. Rod 38 has been shown with a threaded connection, at its ends, with universal joints 37 and 39. However, the connection may also be formed with splines to enable rotation in opposite directions while preserving the connection.

A shaft 40 is connected to the constant velocity universal joint 39 at one end thereof, and a spur gear 41 having comparatively wide tooth is coaxially secured to the shaft 40. THe spur gear 41 meshes with a pinion 43 pivotally secured to a stud 42 mounted on the reciprocating plate 23. The pinion 43 has teeth wider than those of the spur gear 41. The spur gear 41 is axially slidable while meshing with the pinion 43. The pinion 43 meshes with another spur gear 44 coaxially secured to a shaft 45, which is operatively connected to another shaft 51 through an index gear train. The index gear train includes gears 46, 47 a shaft 48, and gears 49, 50. The shaft 51 extends from the vertically reciprocating plate 23 to the worktable 24, and a gear 52 coaxially secured to the extended end of the shaft 51 meshes another gear 53 at a right angle thereto. A shaft 54 carrying the gear 53 is operatively connected to a chuck shaft 60 at the lower arbor holder 26 through a reducing gear train. The reducing gear train includes gears 55, 56, a shaft 57, and gears 58, 59. The chuck shaft 60 is operatively connected to the spindle 27 of the work W in alignment therewith.

As the motor 31 rotates, its output power acts to rotate the constant velocity universal joint 37 in the proximity of the grinding wheel G through the gears 34, 35, and the shaft 36. Accordingly, the other constant velocity universal joint 39 rotates at the same speed with the universal joint 37 through the connecting rod 38, so that the spur gears 41 and 44 can be rotated through the shaft 40 and the pinion 43. Then, the chuck shaft 60 is rotated through the shaft 45, the index gear train, a direction changing gear trains including the shafts 51, 54, and gears 52, 53, and the reducing gear train. As a result of it, the work W rotates in synchronism with the grinding wheel G, while facing with each other.

In grinding the work, the grinding wheel G and the work W are mounted on the gear grinder, and the grinding wheel side constant velocity universal joint 37 moves together with the grinding wheel head 14 in the following cases; namely, in the case that the grinding wheel head 14 moves in the axial direction of the grinding wheel G in order to shift a particular lead of the grinding wheel G to a position corresponding to a lead of the work W to be ground; in the case that the grinding wheel head 14 is inclined relative to the axis of the grinding wheel G for the sake of inclining the tooth trace of the grinding wheel G by an angle corresponding to the angle of the tooth trace of itself i.e. an lead angle thereof; and in the case that the grinding wheel head 14 moves perpendicular to the axis of the grinding wheel G, so as to grind the work W by bringing the tooth trace of the grinding wheel G to the corresponding tooth trace of the work W. When the position of the other constant velocity universal joint 39 is shifted in response to the shift of the grinding wheel G, the spur gear 41 slides along the pinion 43 while being meshed with it by a distance corresponding to the displacement of the universal joint 39, and the spur gear 41 is indexed there.

Similarly, in grinding helical gears, when the worktable 24 is inclined about the axis perpendicular to that of the work W by an angle in accordance with the helical angle of the work W, and further in the course of grinding the work W, when the worktable 24 moves along the direction of the tooth trace of the work W for vertically moving the work W in the axial direction of the work W while keeping it in contact with the grinding wheel G, the constant velocity universal joint 39 in the proximity of the work W also moves together with the worktable 24. At the same time, the spur gear 41 slides along the pinion 43 while keeping meshed therewith by a distance corresponding to the displacement of the universal joint 39, and the spur gear 41 is indexed there.

When the grinding wheel G or the work W is replaced with one having a different diameter, the grinding wheel head 14 moves, and the constant velocity universal joints 37 and 39 cause the spur gear 41 to slide along the pinion 43 to index it properly.

When the pitch (or module) of the work W is changed, the index gear train including gears 46, 47, 49, and 50 should be changed.

In grinding a helical gear W, when the worktable 24 is turned about the axis perpendicular to that of the work W and inclined so as to bring the tooth trace of the work W to an angular position corresponding to the tooth trace of the grinding wheel G or to its helical angle, the gear 53 rotates about the axis 51 of the gear 52 while keeping meshed with the gear 52 at a right angle.

FIG. 4 shows details of the constant velocity universal joints 37 and 39, and FIG. 5 shows the construction of the slidable portion between the spur gear 41 and the pinion 43. As shown in the figures, a bearing case 61 is mounted above the grinding wheel head 14, and ball bearings 62 and 63 are secured to either end of the bearing case 61, respectively, so as to bit the shaft 36 at both ends thereof. The gear 35 is secured to the shaft 36 at about the center thereof, and the gear 35 meshes the gear 34 secured to the grinding wheel spindle 33. The right-hand end of the shaft 36, as seen in FIG. 4, extends out of the bearing 63, and a coupling 64 of the constant velocity universal joint 37 is coaxially connected to the end of the thus extended portion of the shaft 36. One end of the connecting rod 38 is fitted in a movable member 37*a* of the constant velocity universal joint 37 and secured thereto.

A slide block 65 is secured to the back surface of the vertically reciprocating plate 23 in the column 21, and ball bearings 66 and 67 are mounted in either end of the slide block 65, respectively, for fitting the shaft 40. The spur gear 41 is secured to the shaft 41 and meshed with the pinion 43 pivotally supported by the stud 42 through ball bearings 68 and 69, which stud is secured to the reciprocating plate 23. The left-hand end of the shaft 40, as seen in FIG. 5, extends out of the ball bearing 66, and another coupling 70 is coaxially secured to the end of the thus extended portion of the shaft 40. The constant velocity universal joint 39 is connected to the coupling 70, and the opposite end of the connecting rod 38 is fitted in a movable member 39*a* of the constant velocity universal joint 39 and secured thereto.

Cylindrical covers **71** and **72** are secured to the bearing case **61** and the slide block **65**, so as to surround the constant velocity joints **37** and **39**, respectively. A cover bellows **73** for the connecting rod **38** is secured to the covers **71** and **72** at either end thereof by wire bands **74** and **75**, respectively.

The grinding wheel head upper board **13** supports the grinding wheel head **14** at one side thereof and the grinding wheel truing mechanism **5** on the opposite sides thereof, as depicted in FIG. **2**. The grinding wheel truing mechanism **5** comprises a base board **81** mounted on the grinding wheel head upper board **13** so as to be slidable thereon in parallel with the grinding wheel spindle **33**, a holder **82** mounted on the baseboard **81** so as to be movable cross to the grinding wheel spindle **33**, and a handwheel **83** to actuate the cross movement of the holder **82**. A motor **84** (for truing the grinding wheel) is mounted on the grinding wheel head **14**, and the motor **84** has a joint **85** connected to a shaft **86** having a worm **87** secured thereto. The worm **87** is operatively connected with a screw shaft **96** through a worm gear **88**, a shaft **89** of the worm gear **88**, and another indexing gear train, which includes gears **90**, **91**, **92**, a shaft **93**, and gears **94**, **95**. The screw portion of the screw shaft **96** operatively engages a nut **97** secured to the baseboard **81**.

A gear **98** is coaxially secured to the shaft **89** having the worm gear **88**, and the gear **98** is operatively connected to the grinding wheel spindle **33** through an intermediate slidable pinion **99** and a gear **100** secured to the spindle **33**. For truing the grinding wheel G, a suitable dresser (not shown) is mounted on the holder **82**, and the intermediate slidable pinion **99** is shifted between the gears **98** and **100** so as to mesh with each other. Then, the motor **84** is started to drive the grinding wheel G, and at the same time, the base board **82** is reciprocated through the screw shaft **96**. The truing of the grinding wheel G is carried out by feeding the holder **82** toward the grinding wheel G by turning the handwheel **83**.

For different grinding wheel G having different pitches (modules), the gears **90** and **92** of the indexing gear train are changed.

The details of the grinding wheel shifting mechanism, which axially shifts the grinding wheel G so as to bring its tooth trace to the corresponding tooth trace of the work to be ground, will now be described, referring to FIG. **3**. A handwheel shaft **101** is pivotally supported inside the operating panel **6**, and a handwheel **102** is secured to the outer end of the handwheel shaft **101**. A bevel gear **103** is secured to the inner end of the hand wheel shaft **101**, which is operatively connected to another screw shaft **108** through a bevel gear **104** meshing with the bevel gear **103** at a right angle on the same horizontal level, a gear **106** secured to the shaft **105** of the bevel gear **104**, and a gear **107** secured to the outer end of the screw shaft **108** and meshing with the gear **106** at a right angle thereto. The screw portion of the screw shaft **108** is operatively fitted in a nut member **109** secured to the grinding wheel head lower board **12** supporting the grinding wheel head **14**. When the handwheel **102** is turned so as to rotate the handwheel shaft **101** either clockwise or counterclockwise, the screw shaft **108** is actuated through the bevel gears **103**, **104**, the shaft **105**, and gears **106**, **107**, and as a result of it, the grinding wheel head **14** axially moves together with the grinding wheel head lower board **12** by the engagement of the screw shaft **108** with the nut member **109**.

The handwheel shaft **101** has a worm gear **110** secured to the intermediate portion thereof, which meshes with a worm **112** directly connected to a motor **111** mounted inside the operating panel **6**. For automatic operation of the grinding wheel head **14**, the motor **111** is actuated, and the grinding wheel head **14** can be reciprocated through the worm **112**, the worm gear **110**, and the handwheel shaft **101**.

The grinding wheel in feed mechanism for moving the grinding wheel G perpendicular to the grinding wheel spindle **33** for bringing the tooth trace of the grinding wheel G in contact with the corresponding tooth trace of the work W will now be described. Such mechanism is shown in FIG. **3**, and its details are partially depicted in FIGS. **6** and **7**.

Referring to FIG. **3**, another handwheel shaft **121** is pivotally supported inside the operating panel **6** of the base **1**, and a handwheel **122** is secured to the outer end of the handwheel shaft **121**. A gear **123** is secured to the inner end of the handwheel shaft **121**, which is operatively connected to a screw shaft **134** through a gear **124** meshing with the gear **123**, a gear **127** meshing with a gear **126** secured to a shaft **125** of the gear **124**, a gear **129** secured to the shaft **128** of the gear **127**, a gear **130** meshing with the gear **129** at a right angle thereto horizontally, a gear **132** secured to the shaft **131** of the gear **130**, and a gear **133** meshing with the gear **132**. The screw shaft **134** has the gear **133** secured to its outer end, and its inner end is fitted in a nut member **135** secured to the grinding wheel head base **11** supporting the grinding wheel head **14**. When the handwheel shaft **121** is rotated clockwise or counterclockwise by the handwheel **122**, the screw shaft **134** is actuated through the gears **123**, **124**, the shaft **125**, the gears **126**, **127**, the shaft **128**, the gears **129**, **130**, the shaft **131**, and the gears **132** and **133**. As a result of it, the grinding wheel head **14** reciprocates together with the grinding wheel head base **11** by the engagement of the screw shaft **134** and the nut member **135**.

The gear **127** is also operatively connected to a motor **136** mounted inside the operating panel **6** through gears **137**, **138**, a shaft **139**, and gears **140**, **141**. During operation for grinding the work W, the motor **136** is actuated to rotate the screw shaft **134**, so as to automatically feed the grinding wheel head **14** at a low speed for carrying out the grinding operation.

FIGS. **6** and **7** illustrate the details of the construction of the screw shaft **134**. Referring to the figures, a guide base **151** is mounted on the upper surface of the base **1**, and a pair of roller guides **152** and **153** are mounted on either side thereof, respectively. A bracket **154** is disposed between the roller guides **152** and **153**. Another pair of roller guides **155** and **156** are mounted on the lower end of the bracket **154** at either side thereof so as to correspond with the aforesaid roller guides **152** and **153**. A pair of closed roller chains **157** and **158** are inserted between the roller guides **155**, **156** and the roller guides **152**, **153**, respectively, so that the bracket **154** can be freely slided. A shaft hole **159** is bored at the center of the bracket **154**, and a needle bearing **160** is fitted in the shaft hole **159**. At the same time, a pair of thrust ball bearings **161** and **162** are disposed at the opposing ends of the shaft hole **159**. The screw shaft **134** is pivotally supported by the needle bearing **160** and the thrust ball bearings **161** and **162**.

The screw shaft **134** has a shoulder **163** in the proximity of its left-hand end, as seen in FIG. **7**, and the gear **133** is secured between the shoulder **163** and the thrust ball bearing **162**. Two nuts **164** are screwed to the extreme left-hand end of the screw shaft **134**, so as to hold the other thrust ball bearing **161**. The front end of a shaft **165** of the crowning mechanism, to be described hereinafter, is secured to the end surface of the bracket **154** so as to surround the nuts **164**. A screw portion **134***a* is integrally formed with the screw shaft **134** at the front part thereof and screwed in the nut member **135** secured to the front portion of the grinding wheel head base **11**.

When the gear **132** is rotated either by turning the handwheel **122** or by actuating the motor **136**, the screw shaft **134** is rotated through the gear **133** meshing with the gear **132** while being supported by the bracket **154** at a certain position, so that grinding wheel head **14** is reciprocated through the threaded engagement between the screw portion **134***a* and the nut member **135**.

When the crowning shaft **165** reciprocates in response to the operation of the crowning mechanism, the screw shaft **134** moves together with the bracket **154**, so as to reciprocate the grinding wheel head **14**. In this case, the gear **133** slides along the gear **132** while meshing with it so as to transmit the power through the rotating engagement.

The lead regulative mechanism of the grinding wheel for inclining the tooth trace of the grinding wheel G to an angular position corresponding to the tooth trace of the work W, in response to the lead angle of the grinding wheel G, will now be described, referring to FIG. **8**. As depicted in the figure, the

grinding wheel head **14** is supported on the grinding wheel head upper board **13**, and a roller **171** is inserted between the grinding wheel head upper board **13** and the grinding wheel head lower board **12** through holders **172** and **173** at one end thereof, so that the grinding wheel head upper board **13** can swing about the roller **171** relative to the grinding wheel head lower board **12**. A recess **174** is provided on the grinding wheel head lower board **12** at an end opposing the roller **171**, and a bracket **175** is secured to the recess **174** along the outer edge thereof. A tapped cylinder **176** is rotatably supported in the bracket **175**. The tapped cylinder **176** is held in the bracket by applying a stopper **177** to the outer end thereof, and by engaging a nut **187** to the inner end of the tapped cylinder **176**. A dial **179** is secured to the outer end of the tapped cylinder **176**. A screw **180** is screwed in the tapped cylinder **176**, which screw **180** has graduation **181** inscribed at the outer end thereof. Mounted to the inner end of the screw **180** is a slider **183** having its upper surface tapered downwards as it extends toward the roller **171**. A roller holder **184** is provided so as to face the recess **174** of the grinding wheel head lower board **12**, and a roller **185** is held by the roller holder **184**. The roller **185** is supported by a pair of supporting means **186** and **187** secured to the roller holder **184** in such manner that the lower surface of the roller **185** comes in contact with the upper surface **182** of the slider **183**.

When the tapped cylinder **176** is turned by rotating the dial **179**, the screw **180** fitted in the tapped cylinder **176** reciprocates, so as to reciprocate the slider **183** together with the screw **180**. Thereby, the grinding wheel head **14** swings about the roller **171** through the grinding wheel head upper board **13**.

A feeding mechanism to feed the work W along the tooth trace direction for vertically reciprocating the work W during grinding thereof will now be described, referring to FIGS. 2 and 3. As described in the foregoing, a column **21** is provided on the base **1** along the side opposite to the grinding wheel head **14**, and a hydraulic cylinder means **22** extends vertically in the column **21**, and a piston means (not shown) vertically reciprocates therein. On that surface of the column **21** which faces the grinding wheel head **14**, a pair of guide frames **191** and **192** are secured to the opposing vertical sides thereof, and the vertically reciprocating plate **23** moves between the guide frames **191** and **192**. The reciprocating plate **23** carries the worktable **24** mounted at the center thereof, and the reciprocating plate **23** is connected to a movable portion (not shown) of the hydraulic cylinder means **22**. By actuating the hydraulic cylinder means **22**, the reciprocating plate **23** moves vertically along the guide frames **191** and **192**, so as to move the work W together with the worktable **24**. The velocity of such vertical reciprocation can be steplessly changed.

A tooth trace adjusting mechanism for adjusting the tooth trace of a helical gear to be ground so as to bring the tooth trace of the work W in proper contact with the corresponding tooth trace of the grinding wheel G will now be described, referring to FIGS. **9** and **10**. The vertically reciprocating plate **23** holds the worktable **24** in such manner that the worktable **24** is held by a flange **201** formed on the front wall of the reciprocating plate **23** in a manner rotatable about a shaft **202**. The ring-shaped flange **201** formed on the front wall of the reciprocating plate **23** comes in tight contact with another ring-shaped flange **203** formed on the rear surface of the worktable **24**. A scale **204** indicating the degree of rotation is mounted on one side of the flange **201** of the reciprocating plate **23**, and another scale indicating the angular position is mounted on the corresponding sidewall of the flange **203** of the worktable **24**.

A pair of bearing portions **206** and **207** are formed on the front portion of the reciprocating plate **23** above the aforesaid shaft **202**, and a shaft **208** is fitted to the bearing portions **206** and **207**. An operating portion **209** is formed at the right-hand end, as seen in FIG. **10**, of the shaft **208** projecting out of one side of the reciprocating plate **23**. A worm **212** is secured to an intermediate portion of the shaft **208** between the bearing portions **206** and **207**, with ball bearings **210** and **211** fitted to either end thereof. The worm **212** meshes with a worm gear **213** pivotally secured to the rear wall of the work table **24** with its axis in alignment with the shaft **202**.

When the shaft **208** is turned clockwise or counterclockwise by the operating portion **209**, the worm gear **213** is turned through the worm **212**, so that the worktable **24** rotates in either direction about the shaft **202** together with the work W. The desired angle can be set by using the graduations of the scale **204** on the flange **201** of the reciprocating plate **23** and those of the scale **205** of the worktable **24**.

In manual grinding cycle of the gear grinder, both the grinding wheel G and the work W are rotated, and the worktable **24** is vertically reciprocated at a certain velocity, and the grinding is effected by advancing the grinding wheel G by turning the handwheel **122**. Such manual grinding cycle is suitable for test grinding and for refinishing.

In semiautomatic grinding cycle of the gear grinder, both the grinding wheel G and the work W are rotated, and the worktable **24** is vertically reciprocated at a certain velocity, and the grinding wheel G is fed in by a predetermined amount when the moving direction of the worktable **24** is changed. After a given grinding operation is completed, finish grinding is effected at the position where the present infeed is completed, and then the vertical reciprocation of the worktable **24** ceases. Such semiautomatic grinding cycle is suitable for test grinding, and for gear production in small quantities.

In full automatic grinding cycle, the same procedure as the semiautomatic grinding cycle is followed until the finish grinding is completed, and then the grinding wheel G automatically is returned to the position ready for starting the next cycle.

A crowning mechanism for effecting the crowning operation on the work will now be described, referring to FIG. **3** illustrating its overall construction as well as to FIGS. **11** and **12** showing its detailed construction. Referring to FIG. **3**, a single-groove roller **221** is pivotally supported by a shaft **222** secured to the column **21** above the worktable **24**, and a turn roller assembly **223** having a pair of single-groove rollers is pivotally supported by a shaft **224** secured to the lower portion of the column **21**. Another turn roller assembly **225** having a pair of single-groove rollers is horizontally supported by a shaft **226** in a rotatable manner on one side of the base **1**. A single-groove roller **228** is vertically supported by a shaft **229** secured at one end of a crowning frame **227** mounted on the sidewall of the base **1**. An endless rope **230** is spanned over the rollers **221**, **223**, **225**, and **228**, and a portion of the rope **230** is fastened to the reciprocating plate **23** by a fastening means **231** at a position between the rollers **221** and **223**.

Referring to FIGS. **11** and **12**, a block **232** is provided by the roller **228** to support a template base **233** thereon. A shoulder **234** is formed on the upper surface of the template base **233** at the front side thereof. A template **236** having an convex-shape contact surface **235** is fitted in the shoulder portion **234**, and the template **236** is pressed by a pair of clamp pieces **237** and **238**, and connected thereto by bolts **239** and **240**.

A guide groove **241** is provided on the upper surface of the template base **233** along the longitudinal direction thereof and a clamp plate **243** engages the guide groove **241**, which clamp plate **243** is secured by bolts **242** on the upper surface of a receiver **232***a* engaging the rope **230** at an intermediate portion thereof. The outer surface of the template base **233** at the front side thereof engages the peripheral surface of a guide roller **245** horizontally supported on the block **232** by a shaft **244**, so that the template base **233** can be reciprocated on a horizontal plane.

In grinding the work W, when the vertically reciprocating plate **23** is actuated by a hydraulic cylinder means **22**, the rope **230** fastened to the reciprocating plate **23** reciprocates along the rollers **221**, **223**, **225**, and **228**, so that the template base **233** having the template **236** secured thereto moves back and forth on the block **232**.

A sliding guide base **246** is mounted on the upper portion of the crowning frame **227** secured to the base **1**. A slider **249** is

slidable supported by a pair of projecting guide walls **247** and **248** formed on the opposing sides of the sliding guide base **246**. A hydraulic servomechanism **250** is mounted at one end of the slider **249** for receiving a force from the template **236**.

The hydraulic servomechanism **250** has a rod **251** secured to one end thereof in a reciprocative manner relative to the means **250**, and the rod **251** is urged toward the contact surface **235** of the template **236** by an internal spring (not shown). A substantially conical cap **252** is mounted on the extending tip of the rod **251**, and the tip of the cap **252** is urged against the contact surface **235** of the template **236**.

The hydraulic servomechanism **250** is of known type, and hence, its details are not shown here. In short, it has a hydraulic differential means mounted therein, and when the tip of the rod **251** is depressed by an urging force, the urging force is intensified to a force of predetermined magnitude, so as to produce a moving force. Upon removal of the urging force, it resumes its original position in proportion to the degree of intensification. The degree of intensification can be freely adjusted and can be set at any desired value. Accordingly, when the template **236** moves to urge the rod **251** through the cap **252** in accordance with the configuration of the contact surface **235**, the means **250** moves by a certain distance proportional to the displacement of the depressed rod **251**, so that the slider **249** advances. If the template **236** further moves to gradually release the rod **251** from the depression by the cap **252** in accordance with the configuration of the contact surface **235**, the rod **251** gradually projects and the means **250** also moves in the direction opposite to its previous position by a certain distance proportionate to the projecting displacement of the rod **251**, and accordingly, the slider **249** recedes.

An adjusting base **253** is supported on the slider **249** at the opposite end thereof in such manner that it is rotatable about a pin **254** disposed at the center thereof. A pair of slots **255** and **256** are formed on the opposing ends of the adjusting base **253**, and the adjusting base **253** is secured to the slider **249** by stud bolts **257**, **258** and nuts **259**, **260** through the slots **255**, **256**, respectively. A pair of projecting guide walls **261** and **262** are formed on the opposing sides of the adjusting base **253**, and a slidable plate **263** is slidably held between the projecting guide walls **261** and **262**. The outer end of the crowning shaft **165** is pivotally connected to the slidable plate **263** by a pin **264**. The crowning shaft **165** is supported by a plurality of bearing members **265** at its intermediate portion, and its inner end is connected to the grinding wheel head base **11**, as described in the foregoing. When the template **236** reciprocates, the slider **249** moves through the driven intensifying means **250**, and accordingly, the adjusting base **253** also moves. Thereby, the slidable plate **263** slides between the pair of projecting guide walls **261** and **262** of the adjusting base **253**, and the slidable plate **263** moves at a right angle to the slider **249** in accordance with the inclination of the adjusting base **253**, so that the grinding wheel head **14** can be reciprocated through the crowning shaft **165**.

With the crowning mechanism of the aforesaid construction, by adjusting the inclination of the adjusting base **253**, the extend of the crowning amount can easily be adjusted, including its fine adjustment, and accordingly, various degrees of crowning required and various configurations of the work W can be easily achieved.

The template **236** can be easily replaced with other ones to meet the need of different gear shape and different tooth shape. There is substantially no mechanical load applied to the template, and there is no high accuracy required in the template dimension. The template can be made of iron sheet or the like.

With the gear grinder according to the present invention, various adjustments to meet different conditions of the grinding wheel and the work can be effected very easily, and hence, a high production efficiency is ensured.

Furthermore, when any adjustment is made in response to the change in the conditions of the grinding wheel and the work, the driving mechanism responds to it immediately and accurately, so that highly stable accuracy can be ensured even for fine adjustment.

Therefore, with the gear grinder according to the present invention, various spur gears, helical gears, and the like can be accurately manufactured at a high efficiency, and in addition, heavy grinding can be conducted.

Although the present invention has been described with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example and that various changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

We claim:

1. A gear grinder comprising a base; a grinding wheel; a head supporting the grinding wheel, said head being mounted on said base so as to be movable in longitudinal and transverse direction of said base and pivotable with respect thereto; a worktable for supporting a workpiece to be ground into a gear, said table being mounted on said base so as to be movable in a vertical direction and rotatable within the required helix angle of the workpiece gear; a driving prime mover; a power transmission means for transmitting power from said prime mover to both the grinding wheel and the workpiece gear; and a crowning mechanism for effecting a crowning operation on the workpiece gear, said power transmission means including a first constant velocity universal joint associated with the grinding wheel head and a second constant velocity universal joint associated with said worktable, at least one of said universal joints being connected to a spur gear, said spur gear slidably engaging a pinion, whereby said spur gear slides along said pinion in response to either the vertical movement of the worktable or the movement of the grinding wheel head in the longitudinal and transverse directions of the base.

2. A gear grinder as claimed in claim 1, wherein said prime mover comprises an electric motor; and a spindle having one end adapted to carry said grinding wheel being directly connected to said motor, said spindle further being connected in driving relation to said first constant velocity universal joint; and a gear train being associated with said grinding wheel head.

3. A gear grinder as claimed in claim 2, comprising a grinding wheel inclining mechanism adapted to effect inclination of the grinding wheel so that the lead angle of said wheel in the vertical plane includes the axis of said grinding wheel spindle, said grinding wheel inclining mechanism including a grinding wheel head lower board and a grinding wheel head upper board pivotable relative to said lower board; and a tapered slide for controlling the inclination between said lower board and said upper board.

4. A gear grinder as claimed in claim 1, comprising a vertically reciprocatable plate adapted to pivotally support said worktable; a worm gear secured to said worktable; and worm engaging means on said reciprocatable plate for engaging said worm gear whereby the worktable may be rotated in the plane of the required helix angle of the workpiece gear.

5. A gear grinder as claimed in claim 1, comprising means for determining the degree of crowning to be effected to said workpiece gear, said means including a first roller pivotally fastened to a stationary portion of said grinder in proximity to said worktable, a second roller fastened to said base, an endless rope encompassing and tensioned between said rollers, guide means adapted to guide said rope between said rollers, said endless rope being fastened to said worktable so as to rotate about said rollers in response to vertical movement of said workpiece gear, a template being operatively attached to said endless rope so as to correspondingly move in response to rotation of said endless rope, and an actuator being operatively connected to said template so as to actuate said grinding wheel in response to movement of said template.

6. A gear grinder as claimed in claim 5, comprising a crowning adjusting mechanism including a slider positioned

on said base so as to be slidable thereon in response to movement of said actuator, an adjusting base rotatably secured to said slider, and including a crowning shaft adapted to control the degree of crowning of said workpiece gear in response to the angular position of said adjusting base, whereby the crowning operation on the workpiece gear is effected through suitable magnification in conformance with the shape of the template.

7. A gear grinder as claimed in claim 1, comprising a grinding wheel head base mounted on said gear grinder base so as to be slidable in one direction relative thereto, and a grinding wheel head lower board being mounted on said grinding wheel head base so as to be manually or automatically movable perpendicular to said direction, said grinding wheel head being mounted on said grinding wheel head lower board.

8. A gear grinder as claimed in claim 7, wherein said grinding wheel head base is adapted to be moved whereby said grinding wheel may come into contact with said workpiece gear.

9. A gear grinder as claimed in claim 1, comprising a hydraulic cylinder means including a vertically reciprocatable member, said worktable being secured to said hydraulic cylinder so as to reciprocate in unison with said reciprocatable member.

10. A gear grinder as claimed in claim 5, wherein said actuator comprises a hydraulic servomechanism adapted to be actuated by said template.