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Mesey

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[54] **CONTROL OF TOOTH FLANK GRINDING MACHINES FOR HELICAL GEARS**

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[52] **U.S. Cl.** .... **51/42**, 51/48 HE, 51/56, 90/1.4

[51] **Int. Cl.** **B24b 3/00**

[58] **Field of Search** .... 51/33 R, 33 W, 48 R, 51/48 HE, 95 R, 95 LH, 56, 55, 165.78, 111 R, 118, 42; 90/1.4

[56] **References Cited**

FOREIGN PATENTS OR APPLICATIONS

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Assistant Examiner—Nicholas P. Godici
Attorney—Toren and McGeady

[57] **ABSTRACT**

A control means for a tooth flank grinding machine operating in accordance with the indexing generating method has an arrangement for varying the grinding stroke length during a traverse so that it increases from a minimum at the beginning of a traverse and reduces again towards the end of the traverse, so reducing the over-run of the grinding wheels in the end regions of the traverse. The velocity of the generating motion is controlled concurrently in reverse proportion to the grinding stroke length.

13 Claims, 4 Drawing Figures

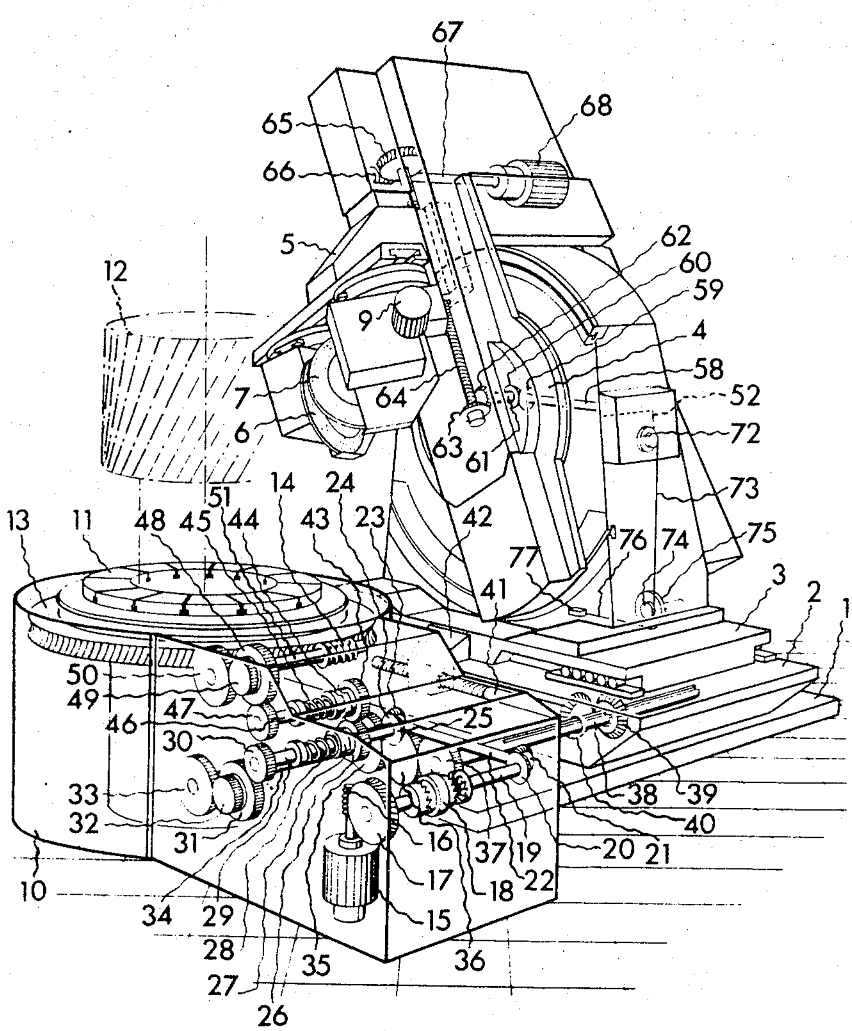

Fig.1

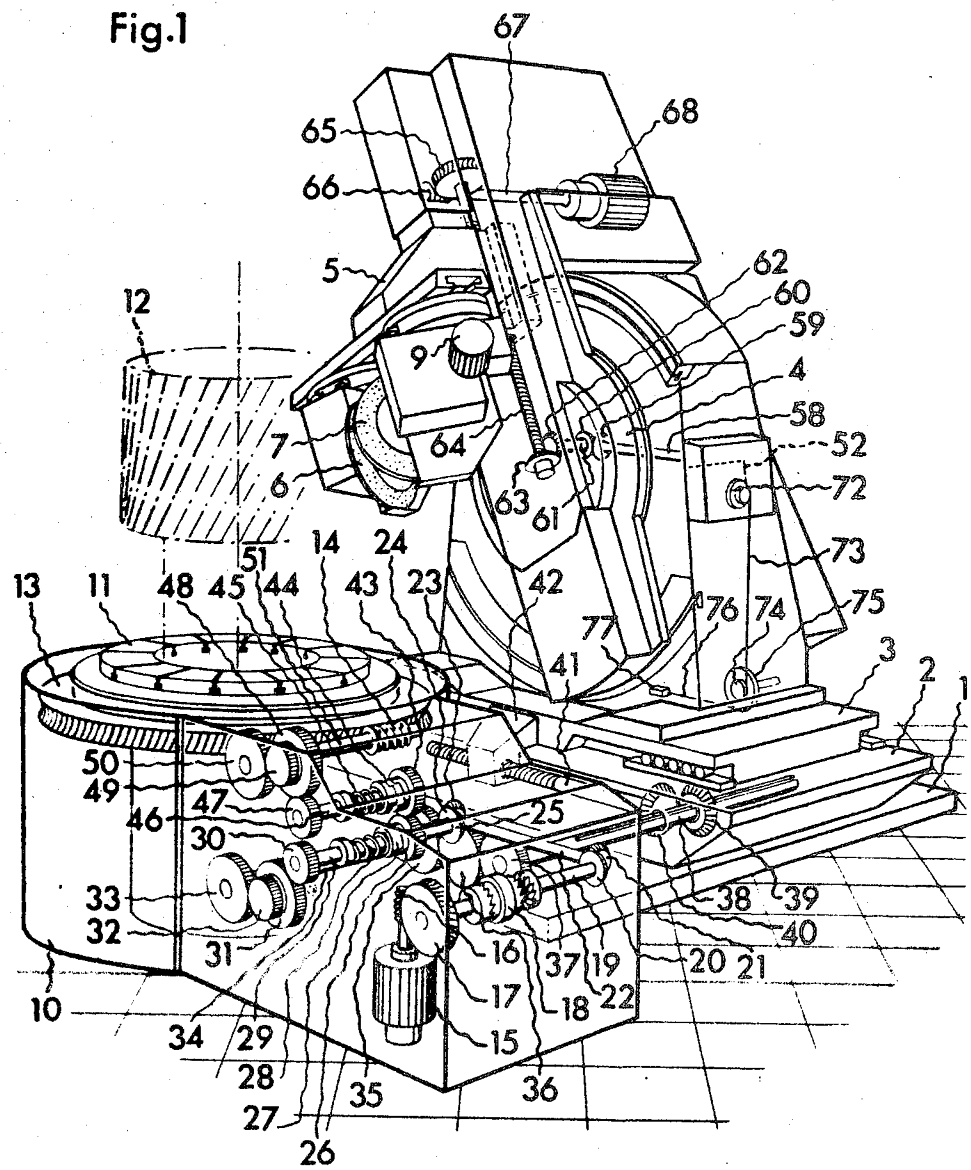
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Fig.2

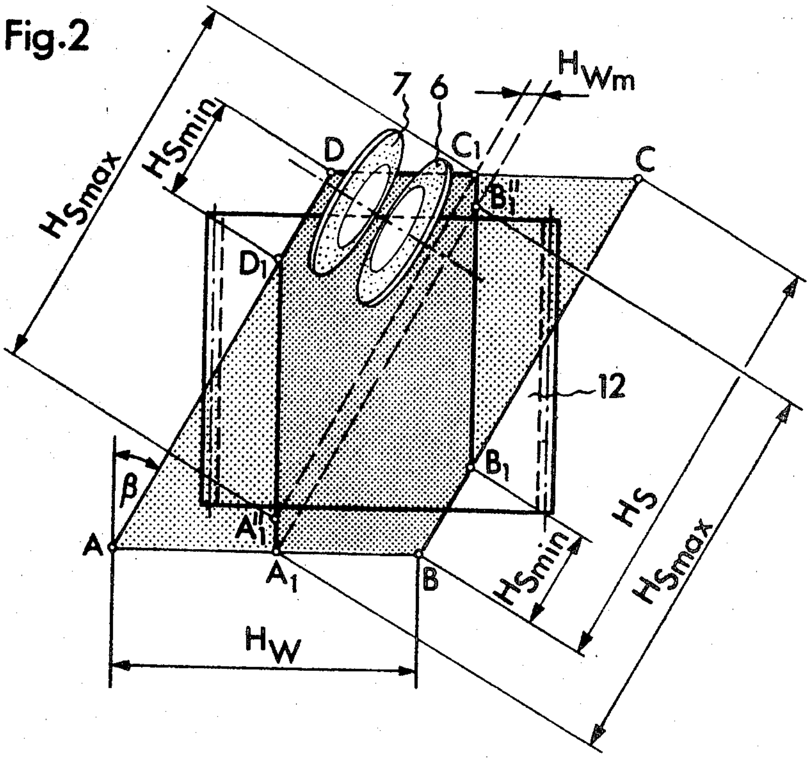
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Fig.3

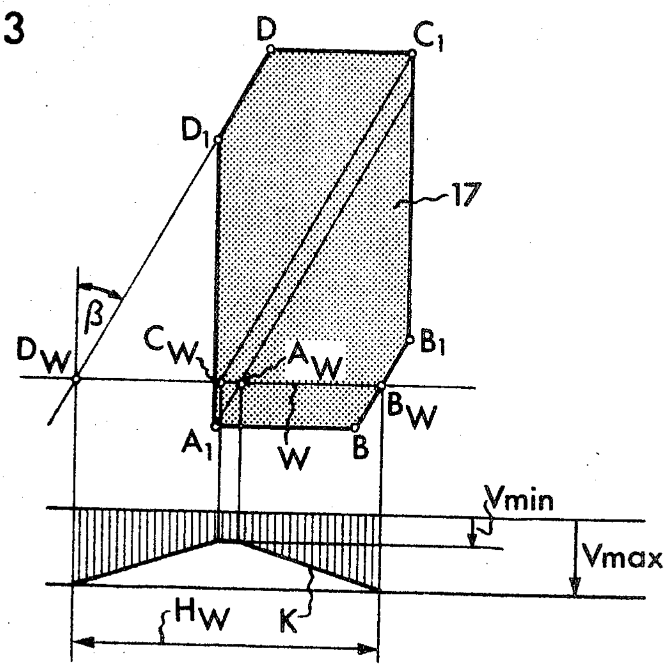
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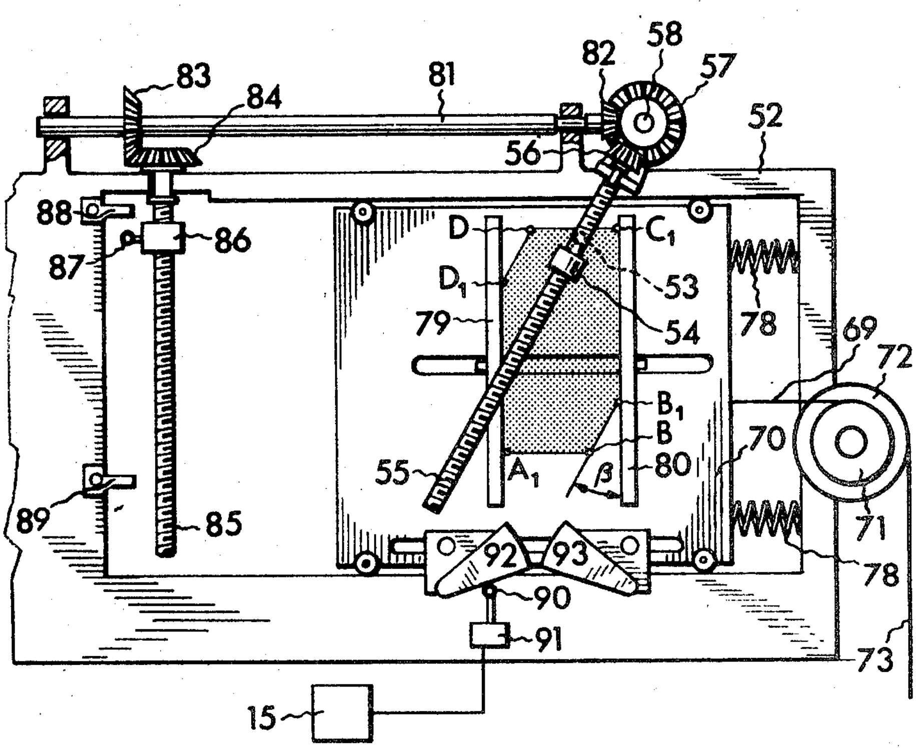
Fig.4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CONTROL OF TOOTH FLANK GRINDING MACHINES FOR HELICAL GEARS

The invention relates to control means on a tooth flank grinding machine for helical gears adapted to operate in accordance with the indexing generating method. Machines of this kind may be used for the so-called 15°/20° grinding method in which there can be two concave conical grinding wheels to machine the left-hand and right-hand tooth flanks, although there are also examples of tooth flank grinding machines known, also adapted to operate in accordance with the indexing generating method, in which one grinding wheel is provided with a double cone adapted to machine simultaneously the left-hand and right-hand tooth flank on both sides of a tooth gap.

In known tooth flank grinding machines during a given grinding cycle the or each grinding wheel sweeps a parallelogrammatic surface with constant stroke length and reversal points disposed on a straight line. Usually only a relatively small part of the stroke is utilized for grinding work, the remaining part of the travel of the grinding wheel or grinding wheels being lost in idle motion. This disadvantage has been reduced in a known tooth flank grinding machine operating in accordance with the indexing generating method (Great Britain Pat. No. 1169261) by virtue of the fact that the stroke position of the grinding wheel is varied during the generating cycle. This achieves a certain saving of time since overall there is less idle movement but the grinding stroke length during a given generating cycle is constant so that the proportion of idle movement is still substantial.

According to the present invention there is provided for use in a tooth flank grinding machine for helical gears adapted to operate in accordance with the indexing generating method, a control apparatus arranged to determine the length of grinding stroke in the traverse of the grinding means of the machine over the generating zone, said apparatus including position-limiting elements determining the reversal points of the grinding strokes and said elements being adapted to act so as to increase the length of stroke from a minimum at the beginning of the traverse of the generating zone to a maximum in a central region of the zone and to reduce the length of stroke again towards the end of the traverse of said zone.

Referring again to the known tooth flank grinding machine mentioned previously, this is provided with control means in which the motion of a ram adapted to support the grinding wheel is controlled by adjustable stop abutments and a switch co-operating therewith, the zone in which the motions are performed depending on the position of an adjustable rail which performs a motion corresponding to the rectilinear component of the generating motion between the workpiece and the grinding member.

To achieve the required function with this type of control means, the stop abutments are adjustably mounted on a guide formed on the ram and the associated switch is retained in a guide, disposed in parallel to the direction of motion of the ram and may be adjusted by means of a screw spindle which extends in the same direction. The rotation of the screw spindle required for adjusting the switch may be provided by means of an electric rotary transmitter which is electrically coupled to a second rotary transmitter. The second rotary transmitter is disposed in the casing of a sensing unit which is mounted on the column bed of the machine. The sensing pin of the sensing unit bears on a rail which is mounted in a workpiece slide and encloses an adjustable angle with the direction of relative motion between the column and the workpiece slide.

In contrast to such an arrangement, when said type of control means is employed in the present invention, it is preferably so constructed that a pair of spaced stop abutments or other members arranged to co-operate with a switch of said switching means to define, in the direction of said rectilinear component motion, limits of a zone in which said switch can be reciprocated at the rate of the ram motion and at an angle to said direction corresponding to the helix angle of the workpiece tooth system.

The stop members may be constructed as linear members or rails forming opposite side limits of the zone of travel of said switch, the boundaries of said zone between the spared linear limits thus formed then being defined by end stop elements which are also adjustable.

If, in the same manner as in the known control means, the switch is mounted on a nut through which a screw spindle extends, it can be advantageous in carrying out the present invention if the screw spindle is coupled to a drive transmission of the reciprocating ram.

The switch is preferably of a form adapted to operate without physical contact with the templates or rails.

The linear stop members are preferably mounted on a control plate so as to be adjustable in the sliding direction thereof, said control plate being adapted to slide at an angle to said members. The guide for the sliding movement of the control plate may be formed on a part of the grinding machine, for example on the machine column, which performs the rectilinear component of the generating motion relative to a rotating machine table; the control plate may itself be coupled to a guide for the aforementioned machine part by means of a reduction transmission.

The additional end stop elements referred to above are preferably associated with a second switch which is also adapted to reciprocate at the rate of the ram stroke. The second switch is conveniently carried by a second nut through which a second screwed spindle extends which is also coupled to the drive of the reciprocating ram.

In a preferred emboidment of the invention, the stop members are coupled with a control cam which controls the generating velocity so that they operate in conjunction therewith, said cam control being exercised so that said velocity diminishes with an increasing length of ram stroke and increases with a decreasing length of ram stroke. In a middle portion of the traverse zone, corresponding to a region with uniform maximum length of ram stroke, the control cam may have a rectilinear characteristic, parallel to its direction of motion to give a series of uniform velocity storkes. In a preferred embodiment the control cam comprises two control arms which are adjustably mounted on the control plate. The cam can have a follower member that is the adjusting member of a potentiometer which controls the rotational velocity of an electric motor for the generating motion.

As an illustrative embodiment of the invention, a tooth flank grinding machine according to the invention is shown diagrammatically in the accompanying drawings in exemplified form for the 15°/20° grinding method. In the drawings

FIG. 1 shows the general construction of the machine in perspective;

FIG. 2 shows schematically the workpiece to be ground with two grinding wheels disposed in front thereof and the surface traversed by the grinding wheels, which includes some over-run;

FIG. 3 shows schematically the same surface traversed as in FIG. 2, together with a corresponding diagram of the generating velocity referred to a horizontal base line, and

FIG. 4 shows a control unit for the machine of FIG. 1, the surface traversed by the grinding wheels being marked in analogy with the schematic illustration in FIGS. 2 and 3.

Referring to FIG. 1, the tooth flank grinding machine is mounted on a baseplate **1** on which a platen **2** is carried in longitudinally slidable manner. A column **3** is disposed to slide transversely on the sliding platen **2** and a pivoting plate **4** for adjusting the helix angle β of the teeth to be ground is adjustably mounted on said column. The pivoting plate **4** has a ram guide formed on it, a ram **5** being adapted to reciprocate in the direction of the tooth helix angle on said guide. Two convex conical disc-shaped grinding wheels **6** and **7** are carried by the ram **5** so that their grinding planes are disposed at the operative angles of 20° respectively of the teeth to be ground. Each of the two grinding wheels **6** and **7** is driven by a separate motor **9**.

A bed **10** for a rotatable workpiece table **11** with a vertical axis is mounted on the baseplate **1** and a gearwheel **12** which is to be ground is clamped on the table **11**. A wormwheel **13**, driven by a worm **14**, is secured to the workpiece table. The generating motion is compounded by a rotating motion of the table **11** with the workpiece **12**, and a corresponding tangential motion of the two grinding wheels **6** and **7** resulting from transverse displacement of the column **3**. These motions are produced by a generating motor **15** which is mounted on the bed **10** and drives a shaft **19** through a generating worm **16**, a generating wormwheel **17** and a generating clutch **18**.

The drive for the transverse displacement of the column **3** is derived from the shaft **19** through two bevel gears **20** and **21**, a shaft **22**, two bevel gears **23** and **24**, a shaft **25** on which a gearwheel **26** is mounted, a clutch **27** with clutch spring **28** and a shaft **29**, module change gears **30, 31, 32** and **33** and a shaft **34** with a gearwheel **35**. The drive is then transmitted from there through an intermediate gear **36** to a gearwheel **37** which is mounted on a shaft **38**. The rotary motion of the shaft **38** is transmitted to a bevel gear **39**, from there to a bevel gear **40** and a module spindle **41**. The module spindle **41** engages with a nut **42** which is mounted on the column **3** and so displaces the column **3** transversely.

The drive for the rotary motion of the workpiece table **11**, and therefore of the gearwheel **12** which is to be ground, is taken from the gearwheel **26** and comprises a gearwheel **43**, a clutch **44** with clutch spring **45**, a shaft **46** and gearwheel **47** mounted thereon and functioning as a first change gear for adaptation of the table motion to the number of teeth on the workpiece to be ground. Further change gears **48, 49** and **50** mesh with the change gear **47**. The last-mentioned change gear **50** is secured to a shaft **51** that also carries the worm **14** and thus drives the table **11** with the gearwheel **12** which is to be ground.

The tangential motion of the column **3** is matched to the rotating motion of the workpiece **12**, by means of the module change gears **30** to **33** and the change gears **47** to **50**, thus producing the generating motion between the grinding wheels **6** and **7** and the workpiece **12**.

Referring now to FIG. **2**, given a stroke H_S of the grinding wheels **6** and **7**, adapted to traverse the entire tooth width with a slight over-run as hitherto, and given a generating path H_W, the area traversed by the grinding wheels will be a parallelogram A B C D. Within the parallelogram, the traverse area actually required for grinding the tooth flanks is further defined by the two perpendicular lines B_1 C_1 and D_1 A_1. The resultant surface area, namely A_1 B B_1 C_1 D D_1, marked in FIGS. **2, 3** and **4**, represents only approximately 60 percent of the parallelogram A B C D in the illustrated example. To traverse this reduced area, at the beginning of the generating motion the grinding stroke will be of minimum length HS min; it then increases to the maximum length HS max in the middle zone HWm of the generating motion and then diminishes towards the end of the generating motion to the minimum length HS min again.

A control unit **52**, shown in detail in FIG. **4**, is provided for controlling the grinding stroke, that is to say the length, position and reversing points thereof. The unit comprises a first switch **53**, adapted to operate without physical contact, as for example a magnetically or photoelectrically operated switch, mounted on a nut **54** which is reciprocated in synchronism with the motion of the grinding wheels **6** and **7** along a spindle **55** by opposite rotational movements of the spindle. The spindle **55** is coupled through bevel gears **56** and **57** to a shaft **58** and this in turn is coupled through bevel gears **59** and **60** in the centre of the pivoting plate **4** to a shaft **61** that is driven by a ram spindle **64** through bevel gears **62** and **63**. The ram spindle **64** is itself driven through a wormwheel **65**, a worm **66** and a shaft **67** by a reversing motor **68** to reciprocate the grinding wheels **6** and **7**.

The control unit **52** also comprises a control plate **70**, positioned so as to be horizontally slidable in the unit, one end of a wire rope **69** being mounted on said control plate. The wire rope **69** runs over a small pulley **71** which is mounted on a larger pulley **72**, supported in the column **3**. One end of a second wire rope **73** is mounted on the pulley **72** and the other end of said wire rope is mounted on a smaller pulley **74**. A larger pulley **75** is coaxial with and fixed to the smaller pulley **74** and both are supported together in the column **3**. One end of a third wire rope **76** is mounted on the large pulley **75**, the other end of said wire rope being attached to a block **77** of the sliding platen **2**. The pulleys **71, 72** and **74, 75** function as a reduction transmission and transfer the tangential generating motion between the column **3** and the sliding platen **2** to the control plate **70**. The wire ropes **69, 73** and **76** are tensioned by means of two springs **78** which bias the control plate **70**.

Two control rails **79** and **80** acting as spaced stop members are mounted on the control plate **70** for coaction with the switch **53**. The control rails **79** and **80** extend at an angle, in the illustrated example 90°, relative to the direction of motion of the control plate **70**, and relative to the longitudinal axis of the spindle **55** they each subtend an angle corresponding to the helix angle of the teeth of the workpiece and are adjustable parallel to themselves towards and away from each other.

The control unit **52** also incorporates a shaft **81** which is rotationally coupled through bevel gears **82, 83** and **84** to a threaded spindle **85** that engages a nut **86** on which a switch **87** is disposed. Opposite end limiting positions of the switch **87** are defined by separate stop abutments **88, 89** respectively and these limiting positions correspond to the upper and lower limiting position of the ram **5.** The distance between these positions therefore corresponds to the hypothetical ram stroke H_S.

The reciprocating motion of the ram **5,** produced by the reversing motor **68** and corresponding to the line B-B_1 begins when the tooth flanks of the gearwheel **12** are first contacted by the two grinding wheels **6** and **7.** By the operation of the control apparatus described above, the grinding stroke then has the length HS min shown in FIG. **2.** This is achieved by virtue of the switch **53,** which co-operates with the control rail **80** as it reciprocates at the same rate as the ram **5** to provide the upper limit of the stroke. The lower limit of the stroke is provided by the switch **87,** co-operating with the stop abutment **89** and also reciprocating at the same rate as the ram **5.**

The generating motion starts simultaneously with the ram motion: the generating motor **15** turns the gearwheel **12** and drives the column **3** to produce the appropriate tangential motion thereto. Accordingly, the control plate **70** of the control unit **52** is also moved so that the grinding stroke, limited at the top by the control rail **80** and limited at the bottom by the stop abutment **89,** is gradually increased from B-B_1 to A_1-B_1'' when it will have assumed the magnitude H_{Smax}. The lower limit of the grinding stroke H_{Smax} to the line A_1''-C_1 is then controlled by the control rail **79** in the further course of the generating motion. Further generating movement causes a reduction of the grinding stroke length which will then be defined at its bottom limit by the control rail **79** and at its top limit by the stop abutment **88,** until the line D_1-D is reached, corresponding to the minimum grinding stroke length HSmin. The tooth flanks will then be finish ground.

Owing to the ram **5** being driven by the reversing motor **68** and the ram spindle **64,** the speed of the ram will be constant — with the exception of the brief reversing point zones — because of the preselected speed of the reversing motor **68.** The speed of the reciprocating motion of the two grinding wheels **6** and **7** will thus also be constant. This arrangement ensures that the grinding stroke rate per unit time is approximately inversely proportional to the grinding stroke length: the shorter the strokes, the greater their frequency; the longer the strokes, the smaller their frequency.

The generating speed is determined by the rotational speed of the generating motor **15,** which in turn depends on the position of a cam follower roller **90** of a potentiometer **91** as indicated in FIG. **4.** A horizontal W (FIG. 3) corresponding to the lower end face of the workpiece **12** extends through the area A_1-B-B_1-C_1-D-D_1 traversed by the grinding wheels. The point B_W corresponds to a required maximum generating velocity v_{max}, the portion of the generating traverse along the line W between points A_W to C_W to a required minimum generating velocity v_{min} and the point D_W again to the maximum generating velocity v_{max}. The generating velocity over the traverse of the area is thus required to vary in accordance with the curve K.

The required velocity characteristic is obtained by a form of cam that includes elements **92** and **93** adjustably disposed on the control plate **70** of the control unit **52** to perform the function of obtaining the inclined sections of the curve K in FIG. **3.** The horizontal section of the curve K is obtained by an intermediate part of the cam formed by a horizontal edge of the control plate **70** between the elements **92, 93.** The potentiometer **91** is mounted on the control unit **52.** If the control plate **70** is displaced in synchronism with the generating motion, the cam elements **92** and **93** will influence the rotational speed of the generating motor **15** through the roller **90** of the potentiometer **91,** since the potentiometer is mounted on the control unit, thus providing the velocity characteristic shown at the bottom of FIG. **3.** Optimum values are obtained if the generating velocity varies in inverse proportion to the grinding stroke length.

Because of the angular position of the spindle **55,** corresponding to the tooth helix angle β, the length of grinding stroke will vary automatically relative to the tooth helix angle. The length of grinding stroke remains constant if the tooth helix angle is 0°; it will then be defined by only the two stop abutments **88** and **89,** which would be adjusted in accordance with the tooth width of the workpiece **12.** Given a hypothetical tooth helix angle of 90°, the length of the grinding strokes would then be defined by only the two control rails **79** and **80,** which would be adjusted in accordance with the generating path or generatrix line in which is the tooth system data for generating the teeth. For all other intermediate values of the helix angle β the programme for controlling the length of grinding stroke and the beginning and end points will be defined by the combined adjustment of the two end abutment stops **88** and **89,** the two control rails **79** and **80** and the angular setting of the spindle **55.** The generating position is the parameter for this.

What I claim and desire to secure by Letters Patent is:

1. In a tooth flank grinding machine for helical gears operating in accordance with the indexing generating method and having control apparatus determining the length of stroke of the grinding means of the machine in the traverse of said means over th generating zone, the improvement comprising position-limiting means in said control apparatus varying the reversal points of the grinding strokes, said means including parts movable in coordinated relationship with the stroke of said grinding wheels, members cooperable with said movable parts for causing the length of grinding stroke to increase from a minimum at the beginning of the traverse of the generating zone to a maximum in a central region of the zone, and other members cooperable with said movable parts to reduce the length of stroke again towards the end of the traverse of said zone.

2. A machine according to claim **1** in which said control apparatus controls the movements of a ram supporting the grinding means and comprises a first switch means and a control plate means having a relative motion to said first switch means determined by the rectilinear component of the generating motion between the workpiece and the grinding means, means being provided for adjusting the relative position of the control plate means and the frist switch means, control stop means having spaced stop elements operable in conjunction with said control plate means, a second switch means cooperable with said stop elements to define limits in said rectilinear motion direction, of a zone of motion of said second switch means, switch drive means actuating said relative motion of said first switch means in a reciprocating manner in synchronism with the ram motion and at an angle to said recilinear component direction corresponding to the helix angle of the workpiece teeth.

3. A machine according to claim **2,** wherein said first switch means is adapted to operate without physical contact with said control plate means.

4. A machine according to claim **2,** wherein a nut carries said first switch means and a screw spindle coupled to the reciprocating drive of the ram supporting the grinding means has said nut threaded upon it whereby the first switch means is reciprocated in synchronism with the ram motion.

5. A machine according to claim **2,** wherein said control plate means includes spaced linear stop members, the zone of travel of said first switch means being defined by the boundaries of the zone extending between said spaced linear stop members.

6. A machine according to claim **5,** wherein means are provided to slidably mount said control plate means in the control apparatus, said linear stop members being mounted on said control plate means to be adjustable relative to the sliding direction of the control plate means, the sliding movement of said control plate means being directed at an angle relative to the linear stop members.

7. A machine according to claim **6,** wherein a part of the machine performing the rectilinear component of the generating motion relative to a rotating workpiece table has a reducing transmission forming a connection to said control plate means to actuate said sliding movement of said control plate means.

8. A machine according to claim **5,** wherein said second switch means cooperates with said stop elements to define the boundaries of the zone of travel of the first switch means, and drive means actuating motion of said second switch means in a recirpocating manner relative to said stop elements and in synchronism with the motion of said ram.

9. A machine according to claim **8,** wherein a nut carries said second switch means and a screw spindle coupled to the reciprocating drive of the ram supporting the grinding means has said nut threaded upon it whereby the second switch means moves in synchronism with the ram motion.

10. A machine according to claim **1,** wherein a control cam is coupled to said control plate means to be displaced synchronously therewith, said control cam determining the generating velocity of the machine and being arranged in such manner that the velocity decreases with increase of ram stroke and increases with decrease of ram stroke.

11. A machine according to claim **10,** wherein said control cam has a middle zone corresponding to the zone of maximum ram stroke, a linear profile being formed on the cam in said middle zone parallel to the displacement direction of the cam.

12. A machine according to claim **10,** wherein said control plate means includes a control plate slidably mounted in the control apparatus and movable in synchronism with the ram, said stop members and the control cam being carried by said control plate, said cam comprising two control bars that are adjustable angularly relative to the control plate, said two bars representing opposite end regions of the cam profile.

13. A machine according to claim **10,** wherein a motor producing the generating motion of the machine is provided with a regulating potentiometer to vary the velocity thereof, said cam having a follower member forming a regulating element of the potentiometer.

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