

Aug. 4, 1931.

L. K. BRAREN

1,817,405

PRODUCTION OF CYCLOIDAL CURVES

Filed Nov. 30, 1926

4 Sheets-Sheet 1

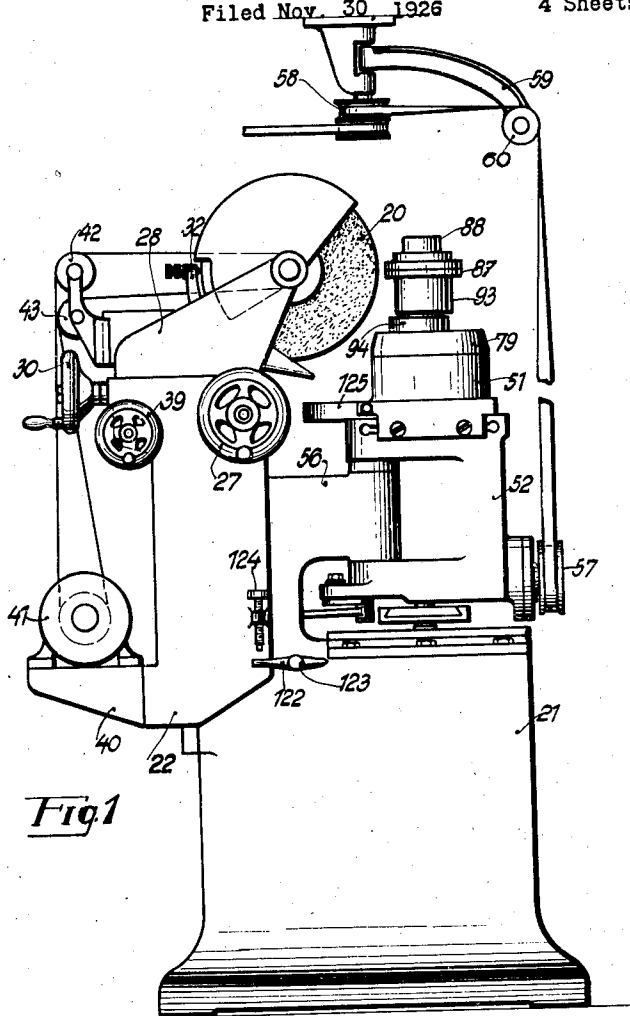


Fig 1

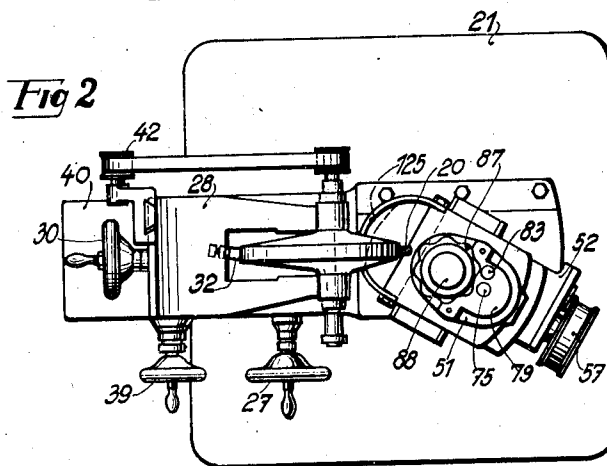


Fig 2

Inventor:
Lorenz Konrad Braren
By
Cumpton & Griffith
his Attorneys

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4 Sheets-Sheet 2

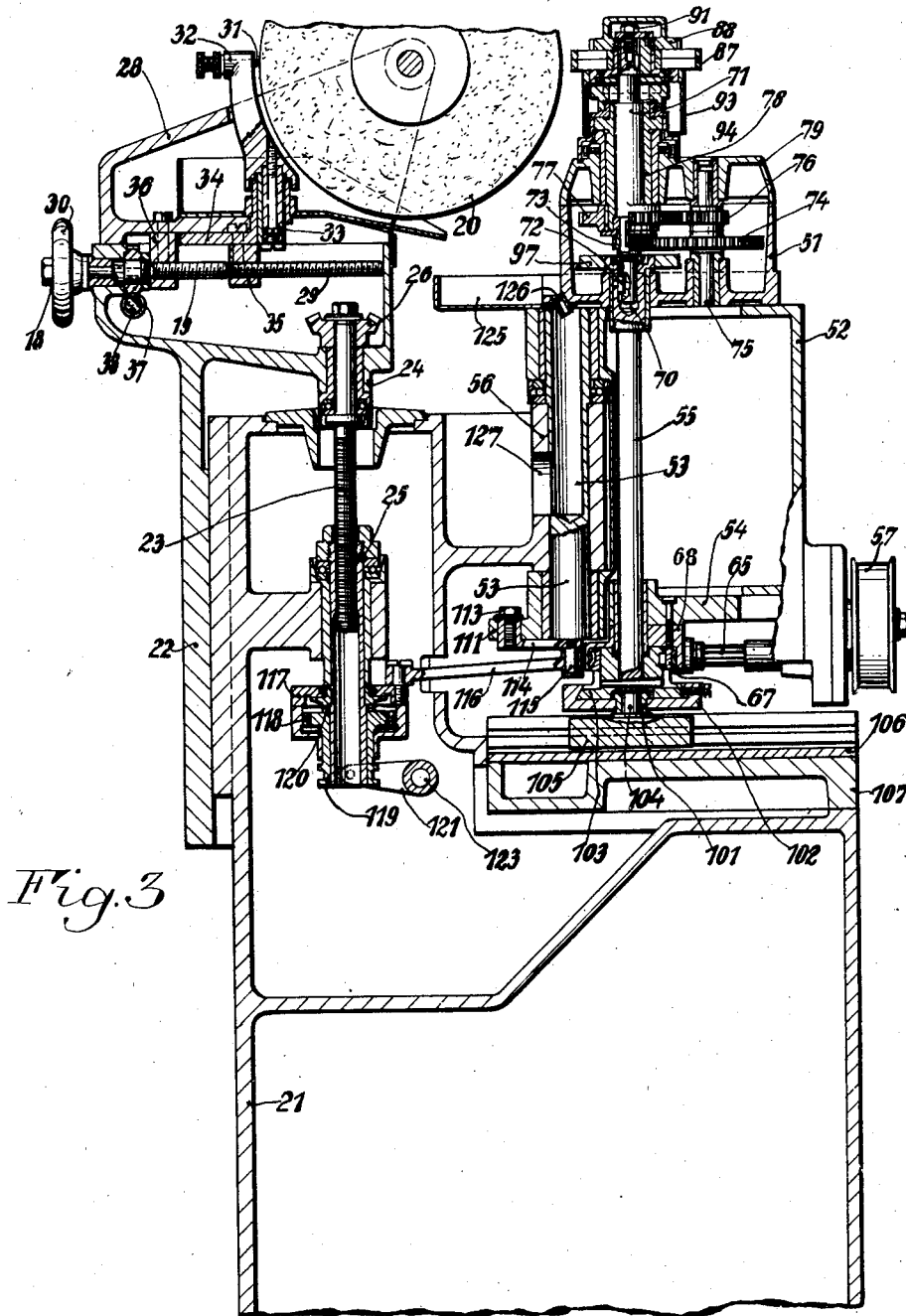


Fig. 3

Inventor
Lorenz Konrad Braren
By *Chapman & Griffith*
his Attorneys

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Fig. 4

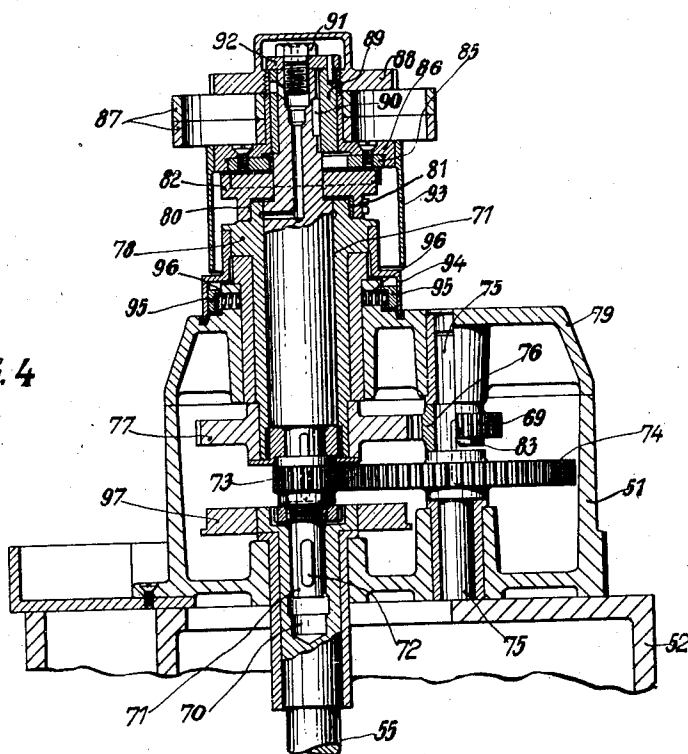
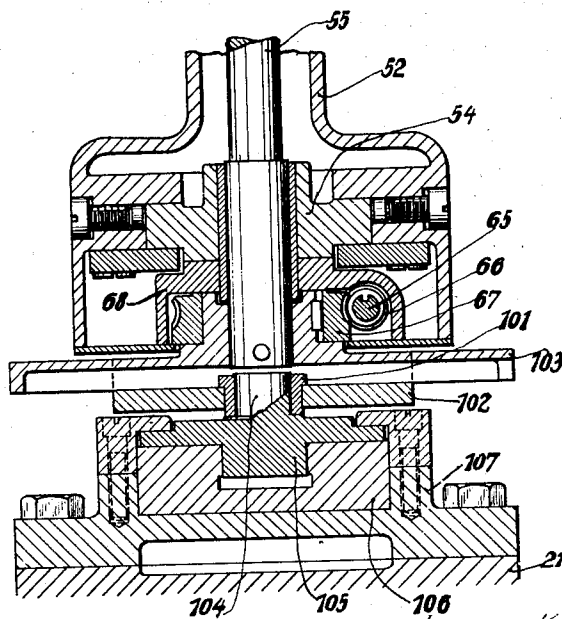


Fig. 5



Inventor
Lorenz Konrad Braren
By *Cumpton & Griffith*
his Attorneys

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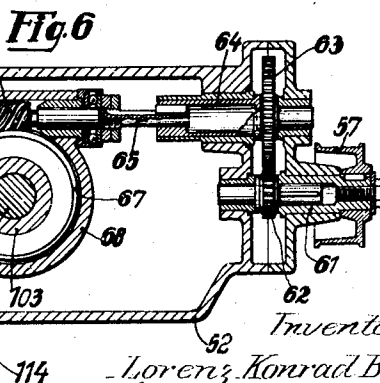
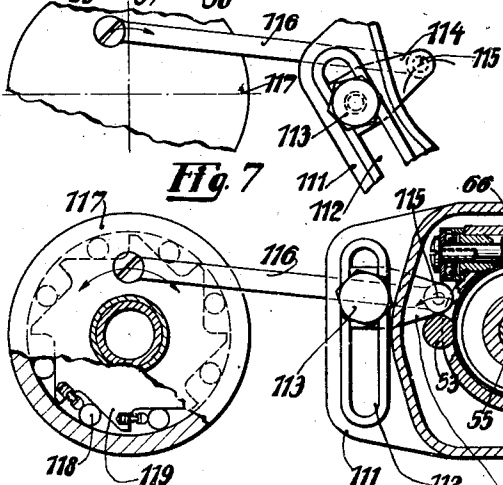
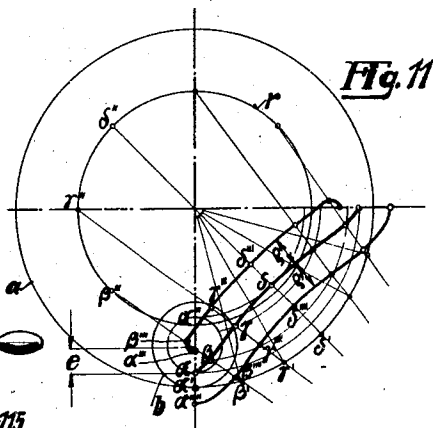
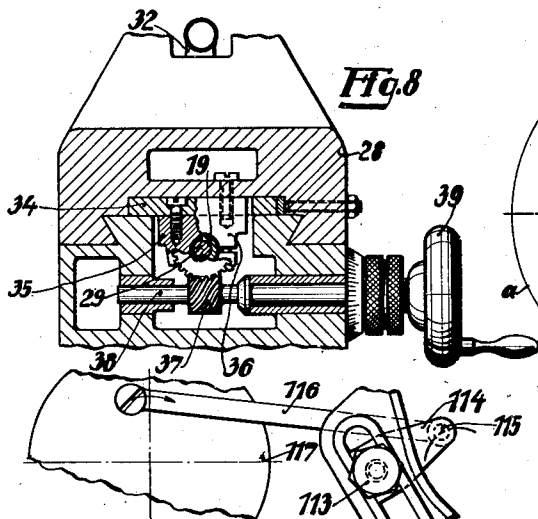
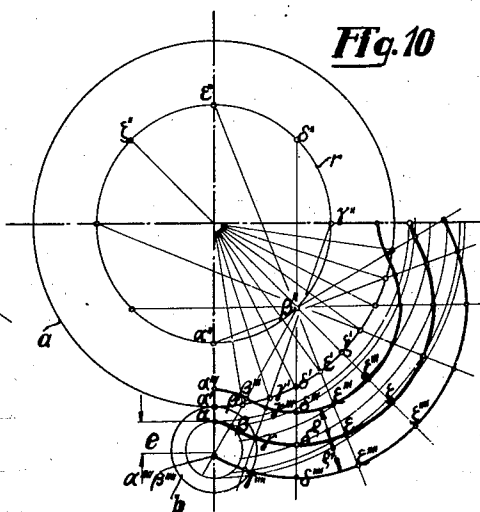
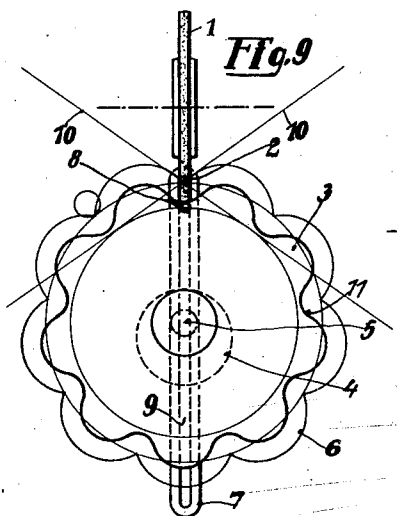
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4 Sheets-Sheet 4



Inventor
Lorenz Konrad Braren
By *Chapman & Griffith*
his Attorneys

UNITED STATES PATENT OFFICE

LORENZ KONRAD BRAREN, OF MUNICH, GERMANY, ASSIGNOR TO FRIEDRICH DECKEL, PRÄZISIONSMECHANIK UND MASCHINENBAU, OF MUNICH, BAVARIA, GERMANY, A FIRM

PRODUCTION OF CYCLOIDAL CURVES

Application filed November 30, 1926, Serial No. 151,799, and in Germany December 5, 1925.

This invention relates to the production of cycloidal curves and the object of my invention is to provide a method and means for generating accurately and rationally such curves. The term cycloidal curve in the following is meant to include epi- and hypocycloids, epi- and hypotrochoids of the prolate or curtate form and of all possible equidistants to the above curves as they may be used for instance in different types of gearing. My copending application "gear transmission" (now Patent No. 1,694,031, dated Dec. 4, 1928) shows how such curves may be used for a specific construction. According to my invention the cutting tool and the work perform two circular movements in relation to each other, whereby it is immaterial whether both these movements are performed by the same part or one by each.

The turning movement around the axis of the system represents the continuous advance of the rolling circle on the base circle, while the movement of the tracing point around the center of the rolling circle is reproduced by a bodily circular movement of the whole part or of the tool. The radius of this circular movement must be equal to the distance of the tracing point to the center of the rolling circle. The angular velocities of both circular movements stand in the following relation.

$$\frac{\text{radius of base circle} \pm \text{radius of rolling circle}}{\text{radius of rolling circle}}$$

The plus sign in this equation stands for an epitrochoid or epicycloid with the two movements in opposite directions and the minus sign is used for hypotrochoids or hypocycloids with both movements in the same direction.

In case both circular movements are performed by the work, for instance a disc, all points of the disc describe cycloidal curves which are more or less deformed. In a certain distance from the center of the system, however, there is described the correct curve and thus it becomes possible to shape the disc to the desired curve by a tool operating at that distance from the center.

A rotating cylindrical cutter with the centerline parallel to the centerline of the system in the correct distance generates an equidistant to the cycloidal curve.

A further important object of my invention is to guide the generating tool to stand always normal to the curve. In case the curve is concave the face of the tool is shaped to a radius smaller than the smallest radius of curvature of the curve.

This object is attained by making use of the following peculiarities of cycloidal curves. It is known that the normal of any point of the curve passes through the point of contact of the rolling circle with the base circle. When moving the rolling circle with constant velocity on the base circle, the normal passes with constant velocity on the base and also on a second circle. This second circle has been found to have a radius equal to the distance of the tracing point from the center of the rolling circle times

$$\frac{\text{radius of the base circle}}{\text{radius of the rolling circle}}$$

The above facts are made use of in the following manner. Either the tool or the work or both are mounted turnably on an axis parallel to the axis of the system and passing through the path of the desired cycloidal curve and are connected to an arm which is oscillated by a crank moving with the angular velocity of the base or rolling circle. When moving the crank with the velocity of the rolling circle the radius of the crank must equal the radius of the above mentioned second circle. When moving the crank with the velocity of the base circle this radius must be equal to the radius of the base circle.

A further object of my invention is to mount the tool on a slide for adjusting the tool in order to produce different equidistants to cycloidal curves. Thus also a wear of the tool may be compensated for. The tool may perform axial reciprocating strokes like a shaper or a rotating tool may be used and the curve shape be produced on a cylindrical body by a slow relative axial movement between tool and work showing as a spiral path on the circumference.

A further object of my invention is to provide a machine entirely automatic in its movement permitting an operator to serve a number of machines.

The above and various other important improvements will be hereinafter fully described and claimed. In order that this my invention may be more readily understood reference is made to the accompanying sheets of drawings which show how the invention may be carried into practical effect.

Fig. 1 is a side view of a grinding machine adapted for this purpose.

Fig. 2 is a top view of the grinding machine shown in Fig. 1.

Fig. 3 is a section of the grinding machine shown in Figure 1 on an enlarged scale.

Fig. 4 is a section of the work carrier on an enlarged scale.

Fig. 5 shows the drive for the work carrier in a vertical section at right angles to the Figure 3.

Fig. 6 is an horizontal section of the same drive on a smaller scale.

Fig. 7 shows the drive for the tool slide on Figure 6 in a different position.

Fig. 8 is a vertical section through the tool slide.

Fig. 9 is a diagram of the method of working.

Fig. 10 shows a prolate epitrochoid and the construction lines used in producing the curve.

Fig. 11 is a similar hypotrochoid.

The tool 1 on Figure 9 is mounted turnably on an axis 2. The work 3 performs a double movement. Once it is moved bodily by an eccentric 4 and it also turns around an axis 5 causing thus points on the circumference of the disc 3 to describe a cycloidal path 6. The swinging movement of the tool 1 is controlled by a lever 7 fastened to the toolholder and by a dog 8 circling around the axis 5 and sliding in a guide 9 of the lever 7. The lines 10 indicate the extreme positions of the tool 1. In case the tool, as shown, does not operate in the point 2 where it would produce the path 6 but at a distance therefrom an equidistant 11 to the cycloidal curve is the result such as are used for instance for some sort of special gearing of which one type is described and shown in my copending application "gear transmission" of the same date as the present application, now Patent No. 1,694,031, above mentioned.

In Figure 10 there is shown an epitrochoid and in Figure 11 an hypotrochoid of which "a" is the base and "b" the rolling circle. The distance of the tracing point from the center of the rolling circle is designated by "c" and "r" is a circle of construction for the normal lines. The Greek letters α , β , γ , etc.

designate identical points on both curves, while α' , β' , γ' , indicate the intersections of the normal with the base circle and α'' , β'' , γ'' , with the circle of construction. Thus, it can readily be seen that for a tool pivoted in the axis of the path α , β , γ , the rocking lever must be guided on the base circle α' , β' , γ' , with the angular velocity of the base circle and on the circle of construction α'' , β'' , γ'' with the angular velocity of the rolling circle. A tool operating in the distance δ on the inside or δ' on the outside of the pivot axis of the tool carrier, of course produces equidistant curves which are designated by the letters α''' , β''' , γ''' and α'''' , β'''' , γ'''' respectively. Instead of mounting the tool to oscillate back and forth the work holder may be as well pivoted to perform the required movement.

A grinding machine is shown as example of the means for performing the method described, although a rotating disc cutter, a cylindrical cutter, a reciprocating tool, a cutting torch, or any other similar tool might be used as well. Of course some minor features of constructions as for instance the arrangement and drive of the tool would have to be altered correspondingly. The machine as described contains a base, a tool on a slide with dressing means, a drive for feeding the tool axially, a work carrier, means for oscillating the carrier, and a drive for the tool carrier.

A slide 22 is held on a dove tailed guide on the base 21 (Figures 1, 2 and 3). A screw spindle 23 journaled in a bore of a hub 24 moves the slide up and down when the supporting nut 25 located in a web of the base is turned. The slide may be adjusted by hand through a pair of bevel gears 26 of which one is fastened to the screw 23 and the other, not shown on the drawings to a shaft and a handwheel 27. The tool, a grinding wheel 20, is mounted in a well known manner in a bracket 28 which is mounted with a dovetailed guide on the slide 22. For dressing the wheel 20 to a radius smaller than the smallest radius of curvature of the curve to be produced there is provided a diamond 31 in a holder 32 which is turnably mounted on a pin 33. The pin is fastened to a small slide 34 (see also Figure 8) which carries a nut 35 in engagement with a screw spindle 29. The pitch of the screw is twice the pitch of the thread on a tubular screw 19 which is arranged on a turned down portion of the spindle 29 for moving the tool carrier 28, a nut 36 being fastened to the carrier. Thus the dressing diamond is moved twice as fast towards the right as the grinding wheel and the cutting side of the wheel after dressing retains in this manner always the same position. A relative adjustment of the grinding wheel and the dressing tool is attained by a spiral

gear 37 on a shaft 38, which is turned by a hand wheel 39, after a nut 18 has been loosened first which clamps a handwheel 30 and the tubular screw 19 to the screw 29. On the slide 22 there is provided a bracket 40 for an electromotor 41 which drives the grinding wheel, the belt passing over guide rollers 42 and 43.

An arm 52 is mounted on a vertical pivot 53 fastened in an arm 56 of the base 21 (Figs. 3, 4 and 5). The arm 52 carries on top a work carrier 51 in a guide extending radially from the pivot axis 53. Similarly there is mounted below the arm 52 a bracket 54 in a radial guide. A main shaft 55 is journaled in the bracket 54 and in the work carrier 51. For driving the main shaft 55 there is provided a pulley 57 which is actuated by a pulley 58 located above the machine, the driving belt passing over guide pulleys 60 on a swinging arm 59. The pulley 57 is fastened on a shaft 61 which carries also a gear 62 (Fig. 6). The latter stands in engagement with a gear 63 fastened to a bushing 64. A key in the hole of this bushing drives a shaft 65 without holding it axially. A worm 66 is part of this shaft 65 and stands in engagement with a wormwheel 67 fastened on the main shaft 55. A bracket 68 holds the shaft 65 in proper relation to the workwheel 67.

The main shaft 55 is provided on the upper end with an axial bore 70 in which a shaft 71 of the work carrier enters, a key 72 forming a driving connection. The shaft 71 carries a change gear 73 which engages a second change gear 74 on a shaft 75. A gear 76 also fastened to the shaft 75 drives a gear 77 over an idler gear 69 on a shaft 83 (see also Fig. 2). The gear 77 is fastened on a sleeve 78 which is journaled in a cover 79 of the tool carrier and provides a bearing in turn for the shaft 71. The upper enlarged end of the sleeve is provided with flats 80 and 81 over which an intermediate member 82 of a cross slide fits. This member 82 carries two faces at right angles to the faces 80 and 81 forming a guide for the upper part 85 of the cross slide the latter attaining thus free moveability sideways. A bushing 86 is fastened by screws to the part 85 and carries the work discs 87, a nut 88 clamping the work. An eccentric sleeve 89 is fastened by a key 90 to the inner shaft 71. The bushing 86 turns on the outside of this sleeve. A screw 91 in the end of the shaft 71 clamps the sleeve 89 by a washer 92 and provides thus an axial guide for the bushing 86. A cylindrical cover 93 is fastened on the bushing 86 for preventing dirt and grinding dust from entering. A similar cover 94 for the same purpose is fastened on the sleeve 78. To remove dead play there are provided brake shoes 95 which are pressed by springs 96 against the inside rim of the cover 94.

For the same purpose a brake disc 97 is fastened on the upper end of the main shaft 55. The brake shoes and springs are not shown on the drawings being located at right angles to the section.

In this manner the work disc receives two distinct circular motions, a slow one through the gears 73, 74, 76, 69 and 77, the sleeve 78 and the cross slide arrangement and a fast one direct through the eccentric sleeve 89, which combined produce the desired shape of curve. An hypocycloid or hypotrochoid results with a turning movement of the shaft 71 and the sleeve 78 in the same direction and an epicycloid or epitrochoid with movements in opposite directions. In order to produce an hypocycloid or hypotrochoid the gear 69 must be disengaged or removed and the gear 76 brought in direct engagement with the gear 77.

The oscillating movements of the work are effected by a bushing 101 (Figures 3 and 5) which is fastened in a slide 102 and can be adjusted to different distances from the center line of the main shaft 55. A member 103 for receiving the adjusting slide 102 is fastened on the main shaft 55. A pin 104 forming part of a second slide 105 is guided by the bushing 101. The slide moves in a guide 106 which is held by an intermediate piece 107 to the base 21 of the machine.

When turning the main shaft 55 the bushing 101 moves in a circle of which the radius depends on the position of the slide 102. The pin 104 however on account of the restriction by the guide 106 can only move back and forth in a straight path. The components of the circular movement at right angles to this path are transferred to the arm 52 and the work 87 with the motion of a swinging block linkage as shown in Figure 9.

In order to use the drive of the work for feeding also the tool there is provided a platelike projection 111 with a slot 112 on the arm 52 (Fig. 6). A bracket 114 is held by a screw 113 in this slot. This bracket carries on the end a bolt 115 which actuates a clutch 117 through a connecting rod 116. The oscillating movement is transferred in well known manner through rolling members 118 into an unidirectional movement of an inner member 119.

The amount of oscillation may be varied considerably by changing the position of the bracket 114 in the slot 112. The inner member 119 is connected to the nut 25 by a tooth coupling 120 and causes thus the feeding motion of the tool. The tooth coupling 120 can be disengaged by an adjustable stop 124 on the slide 22 (Figure 1), a lever 122 on a shaft 123 transmitting the movement to a forked lever 121 which stands in engagement with the inner member 119. The coolant for the grinding wheel is

delivered by a pump not shown. A basin 125 for catching the coolant is provided with an opening 126 conducting it through the hollow shaft 53 and an opening 127 into the suction chamber of the pump.

Having now particularly described and ascertained the nature of my said invention I do not wish to be understood as limiting myself to the exact details of construction as obviously many modifications will occur to a person skilled in the art.

What I claim is:

1. A method for producing cycloidal curves where tool and work perform relatively to each other two circular movements of which the one is a bodily circular movement with an angular velocity equal to the rolling circle and with a radius equal to the distance of the generating point from the center of the rolling circle and the other a turning movement with the angular velocity of the base circle.

2. In a device for producing cycloidal curves, a tool, a work carrier, and means for imparting two circular movements in substantially the same plane to said tool and work carrier in relation to each other, the angular velocity of one movement being a multiple of the angular velocity of the second movement, the two circular movements in combination resulting in cycloidal curves.

3. In a device for producing cycloidal curves, a tool, a work carrier, means for imparting a bodily circular movement to said tool and work carrier in relation to each other, and means for imparting a second relative turning movement to said tool and work carrier, said second movement being in substantially the same plane as the first movement, said bodily circular movement and relative turning movement in combination resulting in cycloidal curves.

4. In a device for producing cycloidal curves, a tool, a work carrier, means for rotating said work carrier, and different means for imparting a second bodily circular movement to said work carrier in substantially the same plane as the rotary movement thereof, the rotation of the work carrier and the bodily circular movement thereof resulting in combination in cycloidal curves.

5. In a device for producing cycloidal curves, a tool, a work carrier, means for rotating said work carrier, and different means for imparting a bodily circular movement to said work carrier in substantially the same plane as the rotary movement thereof, the angular velocity of the second movement being a multiple of the angular velocity of the first movement, the rotation of the work carrier and the bodily circular movement thereof resulting in combination in cycloidal curves.

6. In a device for producing cycloidal

curves, a tool, a work carrier, means for moving said tool and said work carrier in relation to each other to produce cycloidal curves by said tool on the work fastened to said work carrier, and different means for moving tool and work carrier in relation to each other to have the face of the tool stand always normal to the part of the curve worked upon.

7. In a device for producing cycloidal curves, a tool, a work carrier, means for moving said tool and work carrier in relation to each other to produce cycloidal curves by said tool on the work fastened to said work carrier, and a linkage for oscillating said tool and said work carrier in relation to each other for holding the face of the tool always normal to the curve generated.

8. In a device for producing cycloidal curves, a tool, a work carrier, means for causing said tool and work carrier to perform two circular movements in relation to each other which in combination result in cycloidal curves, and a linkage for oscillating said tool and said work carrier in relation to each other, the oscillating period being in time with one of the said circular movements.

9. In a device for producing cycloidal curves, a tool, a work carrier, a drive for causing a bodily circular movement of said tool and said work carrier in relation to each other, another drive for causing a relative turning movement between said tool and said work carrier, and a linkage for oscillating said tool and said work carrier in relation to each other, the oscillation being in time with the drive for the bodily circular movement.

10. In a device for producing cycloidal curves, a tool, a work carrier, a drive for causing a bodily circular movement of said tool and said work carrier in relation to each other, another drive for causing a relative turning movement of said tool and said work carrier in relation to each other, said second turning movement representing the progress of the rolling circle on the base circle and said first circular movement representing the rotation of the rolling circle, a linkage, and a driver forming part of said linkage rotating with the speed of rotation of the rolling circle on a circle of which the radius equals the distance of the generating point from the center of the rolling circle times

$$\frac{\text{radius of the base circle}}{\text{radius of the rolling circle}}$$

11. In a device for producing cycloidal curves, a tool, a work carrier, a driving means for causing a bodily circular movement of said tool and said work carrier in relation to each other, different driving

means for causing a relative turning movement of said tool and said work carrier in relation to each other, both these movements combining to have said tool describe a cycloidal curve on the work fastened to said work carrier, a linkage, a driver forming part of said linkage rotating in time with one of said driving means, and a guide also forming part of said linkage operating together with said driver in transforming the circular motion of said driver into an oscillating movement of said tool and work carrier in relation to each other.

12. In a device for producing cycloidal curves, a tool, a work carrier, driving means for causing a bodily circular movement of said work carrier, different driving means for causing a relative turning movement of said work carrier, both said driving means rotating in fixed relation to each other, and a linkage, consisting of a driver connected to and rotating with one of said driving means and a stationary slide for causing an oscillating movement to be impressed upon said work carrier by the rotation of said driver.

13. In a device for producing cycloidal curves, the combination with a tool, of a spindle, a sleeve rotatably mounted on said spindle, a work support movable relative to said sleeve and operatively connected to rotate therewith, an eccentric portion on said spindle for giving said work support a bodily rotative movement relative to the spindle, means for rotating said spindle, and means for rotating said sleeve relative to said spindle, so that said tool will trace a cycloidal curve on a piece of work carried by said work support.

14. In a device for producing cycloidal curves, the combination with a tool of a frame pivoted to oscillate about an axis, a spindle rotatably mounted on said frame, a sleeve rotatably mounted on said spindle, a work support movable relative to said sleeve and operatively connected to rotate therewith, an eccentric portion on said spindle for giving said work support a bodily rotative movement relative to the spindle, means for rotating said spindle, means for rotating said sleeve relative to said spindle so that said tool will trace a cycloidal curve on a piece of work carried by said work support, and means operated by the rotation of said spindle for oscillating said frame about said pivotal axis to keep the face of said tool normal to said cycloidal curve.

15. In a device for producing cycloidal curves, the combination with a tool, of a frame pivoted to oscillate about an axis, a spindle rotatably mounted on said frame and adjustable toward and away from said pivotal axis, a sleeve rotatably mounted on said spindle, a work support movable rela-

tive to said sleeve and operatively connected to rotate therewith, an eccentric portion on said spindle for giving said work support a bodily rotative movement relative to the spindle, said eccentric portion being adjustable to vary the radius of said bodily rotation, means for rotating said spindle, and means for rotating said sleeve relative to said spindle, so that said tool will trace a cycloidal curve on a piece of work carried by said work support.

16. A method of producing cycloidal curves in which a tool and a piece of work perform relatively to each other two circular movements of which one is a bodily circular movement with an angular velocity equal to that of the rolling circle and with a radius equal to the distance of the generating point from the center of the rolling circle, the other circular movement being a turning movement with the angular velocity of the base circle, and in which method the face of the tool is always held normal to the curve generated.

17. A machine for producing a cycloidal curve on the periphery of a disk, said machine comprising a tool for cooperation with said periphery, a work holder for holding said disk, means for causing said tool and work holder to move relatively to each other through a bodily rotary movement having an angular velocity substantially equal to that of the theoretical rolling circle producing the desired cycloidal curve and a radius substantially equal to the distance of the generating point from the center of the rolling circle, and mechanism for causing said tool and work holder also to move relatively to each other through a rotary movement having an angular velocity substantially equal to the relative angular velocity between the theoretical base circle and a line drawn from the center of the base circle to the center of the rolling circle.

In testimony whereof I hereunto affix my signature.

LORENZ KONRAD BRAREN.