S. T. FONDA.

MACHINE FOR CUTTING TURBINE BUCKETS OR VANES.

APPLICATION FILED JAN. 27, 1902.

973,025. **Patented Oct. 18, 1910.**

4 SHEETS—SHEET 1.

Fig. 1.

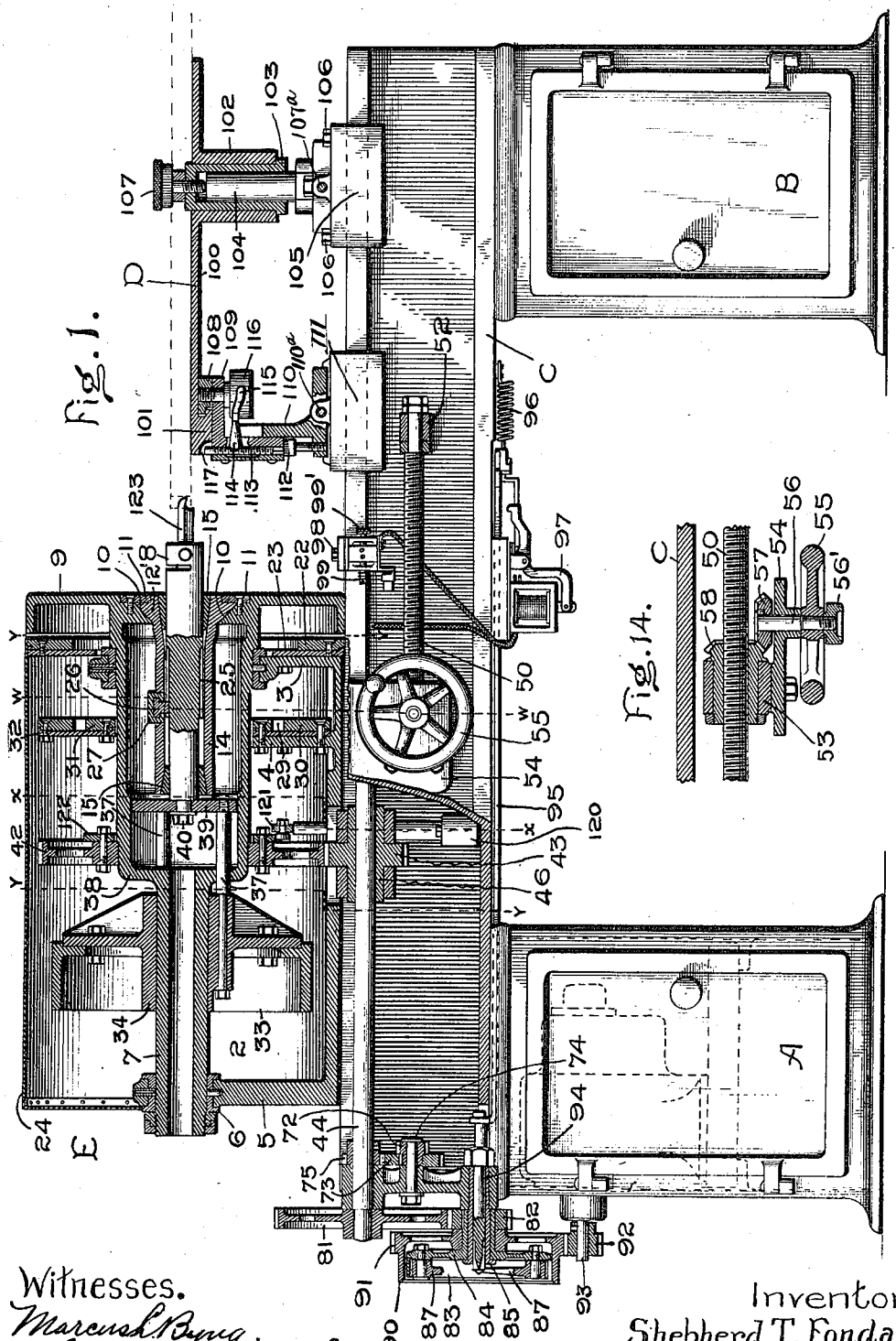

Fig. 14.

Witnesses.

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4 SHEETS—SHEET 2.

Fig. 2.

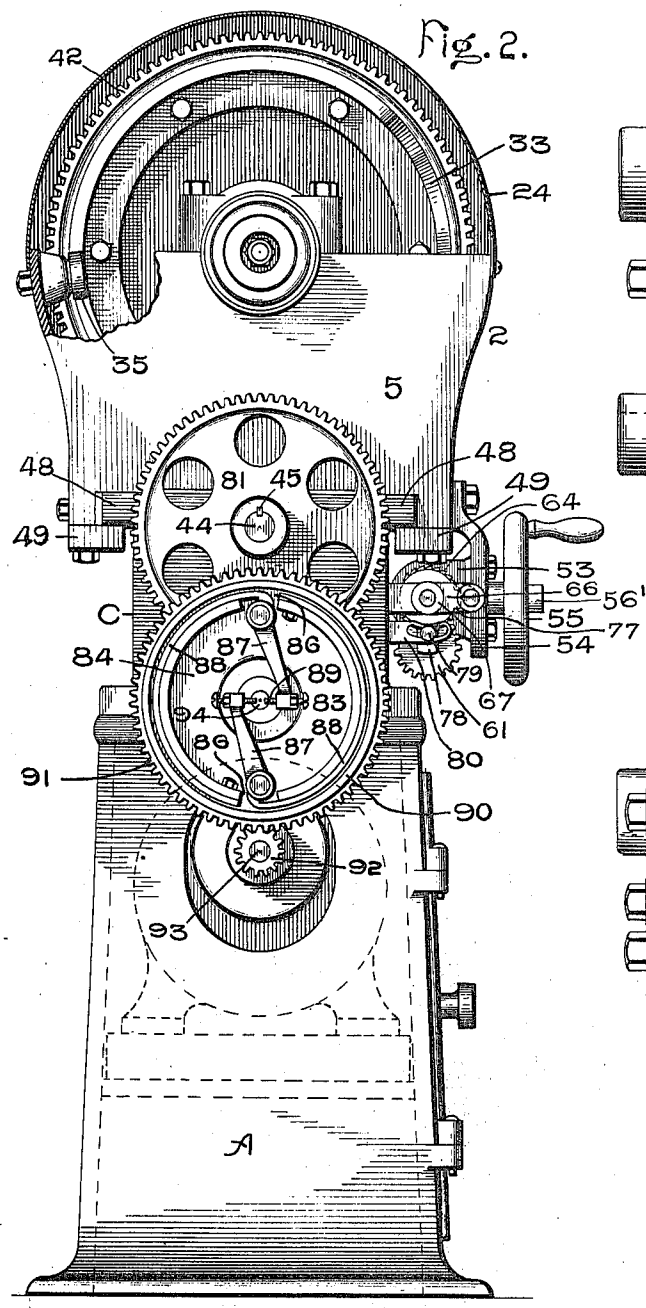


Fig. 3.

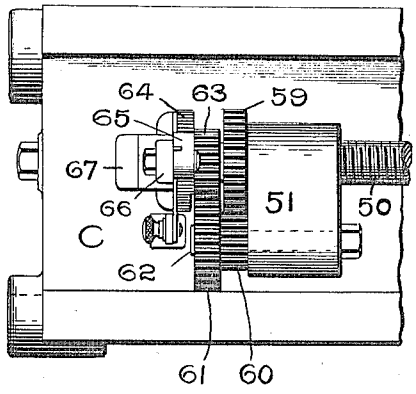
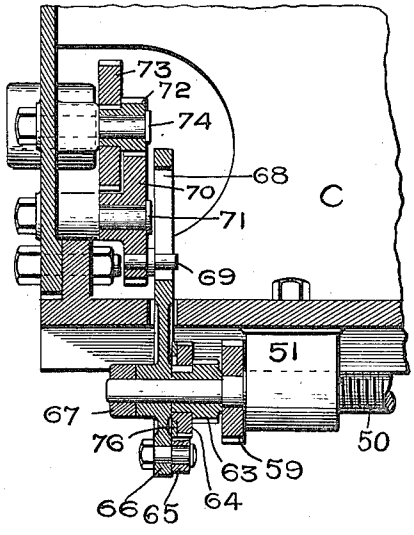


Fig. 4.



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4 SHEETS—SHEET 3.

Fig. 5.

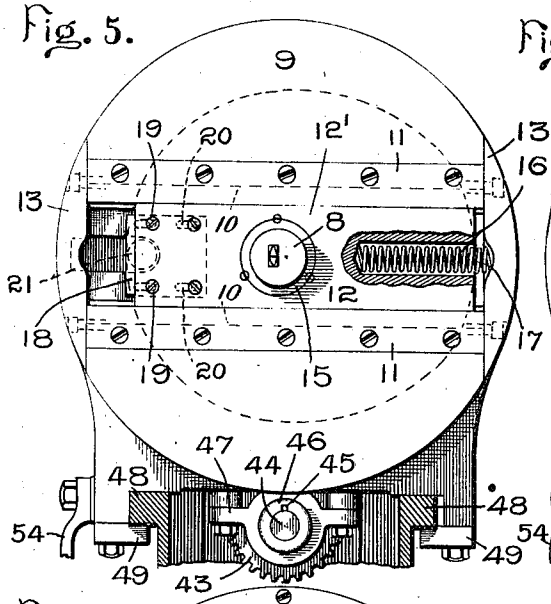


Fig. 6.

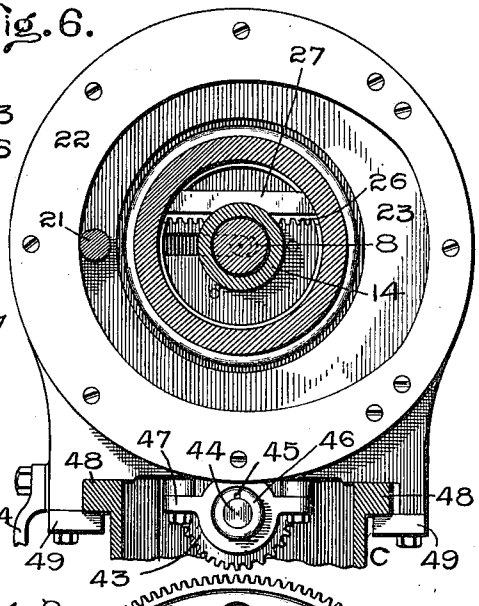


Fig. 7.

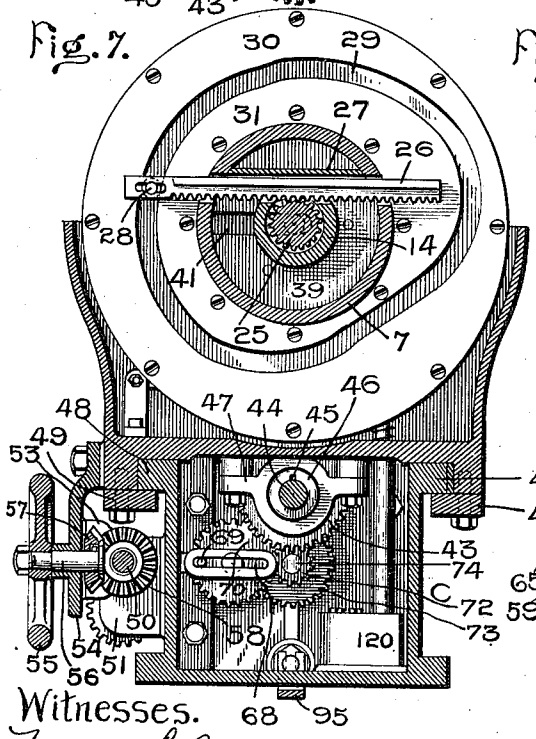
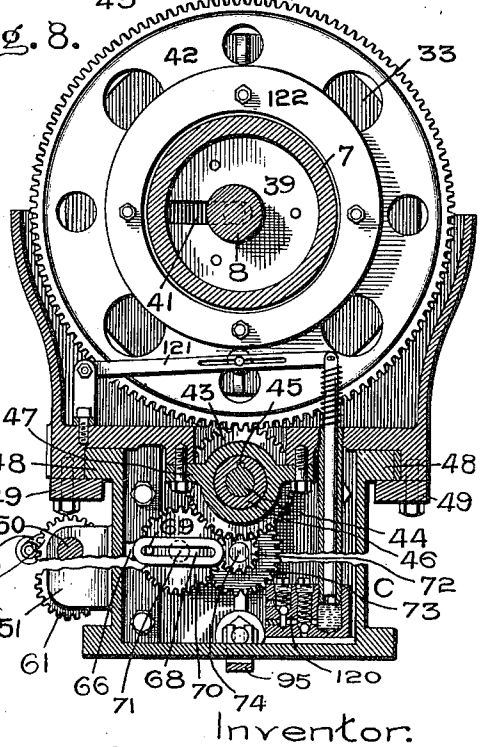


Fig. 8.



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4 SHEETS—SHEET 4.

Fig. 9.

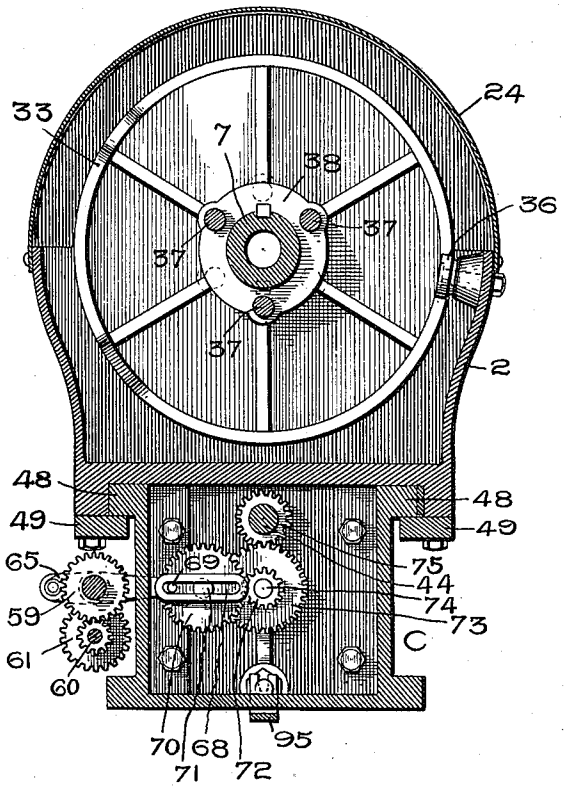


Fig. 10.

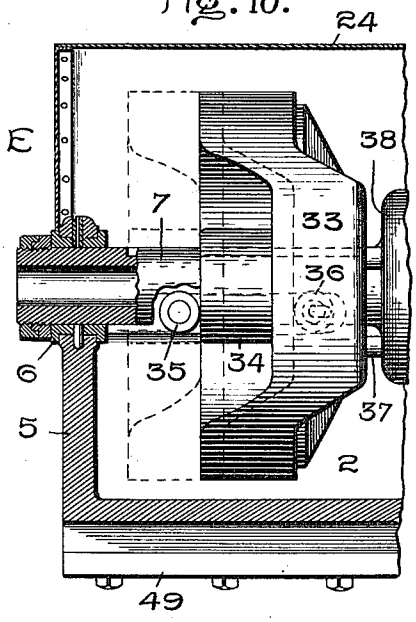


Fig. 11.

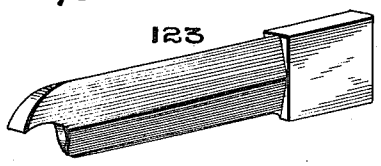


Fig. 12.

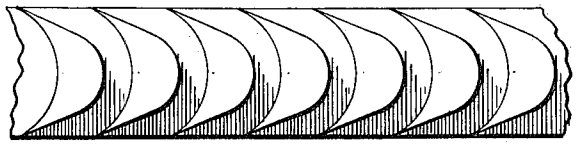
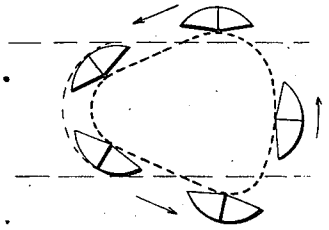


Fig. 13.



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UNITED STATES PATENT OFFICE.

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MACHINE FOR CUTTING TURBINE BUCKETS OR VANES.

973,025. Specification of Letters Patent. Patented Oct. 18, 1910.

Application filed January 27, 1902. Serial No. 91,328.

To all whom it may concern:

Be it known that I, SHEPHERD T. FONDA, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Machines for Cutting Turbine Buckets or Vanes, of which the following is a specification.

My invention relates to metal-working machines, and more particularly to machines for cutting turbine vanes or buckets, and has for its object the production of a metal-working machine which shall be adapted to cut sinuous channels or segments from a piece of metal, or, more specifically stated, from the periphery of a wheel blank whereby the portions of metal left between such channels will constitute properly shaped and finished buckets for steam turbines.

The invention will be more readily understood by reference to the accompanying drawings, forming a part of this specification and in which—

Figure 1 is a side elevation of a machine embodying my invention, with parts shown in section; Fig. 2 is a left-hand elevation of the same, a portion of the head casing being broken away to show the roller of the cam for moving the tool longitudinally; Fig. 3 is an elevation of a portion of the bed of the machine showing the feed gears and lead screw connected thereto; Fig. 4 is a horizontal section of the parts shown in Fig. 3; Fig. 5 is an elevation of the right-hand end of the cutting head with parts broken away; Fig. 6 is a sectional elevation on line *v v*, Fig. 1, showing the traversing cam of the tool carrier; Fig. 7 is a sectional elevation on line *w w*, Fig. 1, showing the cam for controlling the rack for oscillating the tool spindle; Fig. 8 is a sectional elevation on line *x x*, Fig. 1, showing the disk for reciprocating the tool spindle and the pump-actuating cam; Fig. 9 is a sectional elevation on line *y y*, Fig. 1, showing the cam for longitudinally reciprocating the tool spindle; Fig. 10 is a vertical longitudinal section of the rear end of the head casing and bearing, showing the spindle reciprocating cam in elevation; Fig. 11 is a perspective view of the cutting tool; Fig. 12 is a plan of the buckets produced by my machine; Fig. 13 is a diagrammatic view of the path traversed by the tool and also the positions assumed by the tool at different points in said path; and Fig. 14 is a detail view of the means employed to throw the automatic feed into and out of operation.

In carrying out my invention a normally stationary support is provided for the work which may be a disk, ring or segment thereof and in which the sinuous passages are to be cut, and mounted in a reciprocating head or support is a rotary cutting tool. The tool is automatically fed forward until the desired depth of passage is attained, after which the tool is moved backward to the starting position and the blank is angularly rotated until the tool is opposite the place for the next passage, when the cutting action is resumed. The passages cut in the periphery of the blank are sinuous or irregular in outline, and since the tool cuts in one direction only it is necessary to provide means for moving the tool to clear the blank during the idle or return stroke. In carrying out this feature of my invention means are provided, in the present instance comprising a cam which moves the tool backward bodily from the blank during the idle portion of its stroke, and then moves it forward to an operative position. The cutting tool travels, during a portion of its cutting stroke, in the arc of a circle and in an angular direction or path of variable radius during another portion of its stroke; and in order to insure the proper presentation of the cutting edge to the metal at all times, means are provided to rotate the tool slightly independently of the driving and feeding means.

As shown in the accompanying drawings, the machine comprises the supporting frames A and B upon which is mounted the main bed C with the feed mechanism attached thereto and supporting upon its upper surface the work support D and the movable head E carrying the cutting tool and its controlling mechanism. The head E consists of a frame-casting 2 provided with the transverse webs 3 and 4 near its front end, the web 3 being provided with a bearing for the front end of the tubular shaft 7, and the web 5 at the rear end carrying the bearing 6 for the said tubular shaft 7. The tubular shaft 7 extends the entire length of the head E and is enlarged at its front half to provide room in which the tool spindle 8

and connected parts may move transversely. The right-hand end of the tubular shaft 7 terminates in a disk 9 provided with the guide-ways 10, Figs. 1 and 5, and retaining plates 11 for the reception of the transversely reciprocating carrier or support 12 carrying the tool spindle 8. The openings in the disk 9 at the ends of the guide-ways 10 are closed by segmental plates 13, Fig. 5, which are securely held in place by bolts or other suitable means. The transversely reciprocating carrier 12 consists of a plate 12^1 with parallel edges adapted to engage the guide-ways 10 and move freely thereon, and an elongated sleeve 14 extending from the center of the inner face thereof back into the head E and provided at both ends with bearings 15 for the tool spindle or holder 8. One end of the plate 12^1 is provided with a radial recess 16, Fig. 5, for the reception of a coiled spring 17, one end of which seats against the bottom of said recess 16 and the other thrusts against plate 13. Upon the inner surface of plate 12^1 at the opposite end from the recess 16 is provided a radially adjustable bracket 18, the adjustment in the present instance being accomplished by screws 19 and elongated slots 20. The bracket 18 is provided upon its inner face with a projection or anti-friction roller 21. The projection or anti-friction roller 21 engages a cam 22 on the head E and is held in contact therewith by the spring 17 in the opposite end of plate 12^1. The cam 22 consists of a circular disk provided with an eccentric or cam-shaped aperture, and is secured by screws or other suitable connection to the front end plate 23 of the outer casing 24 of the head E, and said end plate 23 is secured to the transverse web 3 of the frame casting 2. By means of this arrangement of the stationary cam 22 and reciprocating spindle carrier 12, the tool is caused to move transversely or radially as the tubular-shaft 7 is continuously rotated.

The tool holder or spindle 8 is given an independent oscillating motion in its bearings 15 by means of an elongated pinion 25 cut in its periphery and a rack 26 (see Figs. 1 and 7), in order to maintain its cutting face at substantially right angles to its path as indicated in Fig. 13. In other words, the rack and pinion keep the tool normal to the cut, which prevents the tool from breaking or dragging. The greatest advantage however in this construction resides in the fact that the tool can be made stronger by reason of the increased amount of stock situated back of the cutting face. This construction also enables the tool to make a smoother cut. Said rack 26 is T-shaped in cross-section, Fig. 1, and is securely held in position and guided by the grooved bar 27 secured to the tubular shaft 7 and passing loosely through one side of the sleeve 14. Longitudinal motion is imparted to the rack 26 as it is carried around by the tubular-shaft 7, by means of the anti-friction roller 28, Fig. 7, mounted thereon near one end, and engaging in the cam-groove 29 formed between the inner surface of plate 30 and the periphery of plate 31. Said plates 30 and 31 are secured in fixed positions on a disk 32 surrounding the tubular shaft 7 and bolted or otherwise secured to the transverse web 4 of the head E.

In order that the tool may clear the work on the return or idle portion of the stroke, a longitudinal traversing motion is provided for, so that said tool will be momentarily retracted after the down or cutting stroke of the same. This longitudinal traversing motion is accomplished by means of the crown-cam 33, securely bolted to the web of the sleeve 34 feathered upon the tubular shaft 7 and adapted to slide freely thereon; said cam 33 engages at opposite sides with the stationary anti-friction rollers 35 and 36, Figs. 2, 9 and 10, mounted upon the inner side of the frame-casting 2 of the head E, and is thereby caused to traverse back and forth upon the tubular-shaft 7 as the same rotates. This traversing motion of the crown-cam 33 is communicated to the tool-holder by means of a plurality of rods 37 connected to the sleeve 34 and extending parallel to the axis thereof through the web 38, which unites the smaller end of the sleeve 7 with its larger end, and connected at their inner ends with a slotted disk 39 which is loosely connected by the nut 40 to the shouldered inner end of the tool-spindle or holder 8. Said plate 39 is slotted at 41, Figs. 7 and 8, to allow for the radial movement of said tool-spindle 8 as above described, and at the same time acts as a guide or support for the inner end of the tool holder.

Rotary motion is communicated to the tubular shaft 7 and the parts connected thereto by means of the gear 42 fixed thereon and engaging the pinion 43 on the longitudinal shaft 44. Said longitudinal shaft 44 is provided with a feather 45, Figs. 5 to 8, for a portion of its length and is supported intermediately in the hub 46 of pinion 43, and said hub 46 is journaled in bearings 47 bolted to the under side of the frame-casting 2 of the head E.

In order to feed the tool the head E is caused to traverse along the bed C toward the work. To provide for this traverse of the head E the bed C is provided with ways 48 at its upper side, and the frame-casting 2 of head E is provided with bearing surfaces on its lower side, and retaining plates 49 securely bolted thereto project beneath the ways 48 on the bed C.

The mechanism for feeding comprises a feed screw 50 supported in bearings 51 and 52, Figs. 1, 3 and 4, projecting from the

front side of the bed C, and engaging a screw-threaded piece in the bracket 53 projecting from the inside of the apron 54, the latter being securely bolted to the head E. The apron 54 is provided with a hand-wheel 55 mounted on a shaft 56 journaled therein and having secured at its inner end a bevel-gear 57 which meshes with the gear 58. The hub of the gear 58 is screw threaded and is operatively mounted on the lead screw 50.

On the outer end of the spindle 56 is a nut 56′, and when this nut is seated the bevel gear 57 remains stationary and locks the gear 58. Rotation of the feed screw under this condition causes the head E to be fed toward the work. When the nut 56^1 is released, rotation of the hand wheel 55 will cause rotation of the gears 57 and 58, and since the latter is provided with a screw-threaded hub, its rotation will cause longitudinal movement of the head. The means for automatically actuating the feed-screw 50 consists of the gear 59 secured to the head end thereof and connected to be driven through the intermediate reducing gears 60 and 61, which are mounted on a stub-shaft 62, Fig. 3, carried by the bearing bracket 51. The gear 63 is loosely mounted upon the head end of the feed screw 50 and meshes with the gear 61. Said gear 63 has feathered upon its hub a ratchet-wheel 64, Fig. 4, adapted to be actuated step-by-step by means of the spring-pressed pawl 65 pivoted at the end of the lever 66 which is also pivoted upon the head end of the lead screw 50 and held in position thereon by the nut 67. The lever 66 is provided with an elongated slot 68 on its inner end for the reception of the crank-pin 69 carried by the gear-wheel 70 mounted on a stub-shaft 71 secured to the end of the bed C. Said gear-wheel 70 is driven from the longitudinal shaft 44 through the intermediate reducing gears 72 and 73 mounted upon the stub-shaft 74, and connected with the gear 75 on said shaft 44. In order to provide means for holding the spring-pressed pawl 65 out of engagement with the ratchet-wheel 64 for a greater or less part of its travel and thereby regulate the rate of feed, a recess is provided in one side of said ratchet-wheel and a ring 76 inserted provided with a segmental projection 77, Fig. 2, which when brought beneath the operative end of the pawl 65 will raise it out of contact with said ratchet 64. Said ring 76 is adjusted and secured in position by means of the depending arm 78 carrying at its lower end the binding screw 79 which enters a slot in the bracket 80 and is adapted to be bound thereon. The longitudinal driving shaft 44 is driven by a gear 81, Fig. 1, secured to the outer end thereof and meshing with a small gear 82 secured to the sleeve of the friction clutch 83. The friction clutch 83, Figs. 1 and 2, consists of an inner flanged disk 84 provided with a central bearing sleeve and mounted to revolve upon a hollow shaft 85 carried by the end of the bed C. The flange of the disk 84 is provided with two recesses 86 diametrically opposite one another. Near these recesses 86 are pivoted levers 87 with their outer ends connected to the clutch-bands 88 and their inner ends extended into proximity to the axis of the clutch and provided with adjustable end bearings 89. Surrounding the clutch-bands 88 is a clutch flange 90 connected at its inner end with a gear 91 loosely mounted on the sleeve of the inner flanged disk 84 and meshing with the pinion 92 fixed upon a motor-shaft 93 so that, when the parts of the clutch 83 are engaged, power is transmitted from the motor-shaft 93 to the longitudinal shaft 44.

The parts of the clutch 83 are controlled by the pointed spindle 94 carried by the hollow shaft 85, which spindle when moved outwardly engages the adjustable end bearings 89 of the clutch levers 87 forcing them outwardly and causing the friction members to engage. The spindle 94 is connected to a rod 95 which is actuated in one direction by a spring 96 and controlled by the magnetically operated latch lever 97, so that when the magnet circuit is closed, the rod 95 will be released and drawn by the spring 96 to the right, withdrawing the pointed end of the spindle 94 from between the ends of the clutch levers and thereby releasing the clutch to stop the rotation of the shaft 44.

The contacts of the magnet circuit are carried on an adjustable support located at the side of the bed C, which support is provided with a clamping bolt 98 for securing it in different positions on the way of the bed C. The contact 99 is spring pressed and is arranged in the path of the head E; and an adjusting screw 99′ extends transversely through the support whereby accurate adjustment may be had. The circuit is closed between the said contacts by the head E moving to the right, and as a consequence thereof the movements of said head are arrested whenever it arrives at the predetermined point upon each advance of the same, thereby producing uniformity of depth of cuts made by the tool.

The work support D consists of a disk-shaped table 100 having a thick peripheral flange 101 and a central bearing sleeve 102 mounted upon a vertically adjustable thrust bearing sleeve 103. The bearing sleeve 103 is made hollow to receive a vertical post 104 mounted upon a transverse supporting frame 105 adapted to be secured to the ways of the bed C by bolts 106. The upper end of the bearing sleeve 103 is tapped to receive the screw 107 adapted to bear upon the upper end of the post 104, so that by turning

said screw 107 the vertical position of the bearing sleeve 103 and support D is adjusted. Since the slot cut by the tool is of uniform width, the vanes are somewhat thicker at their outer ends than at their inner ends. Except in work having a small diameter or vanes of considerable length, this difference in the thickness of the vanes is so small as to be negligible. The screw 107[a] is provided for the purpose of adjusting the support D laterally to permit the vanes to be dressed off to a uniform thickness if desired. The outer edge of the peripheral flange 101 is provided with a series of uniformly spaced recesses 117, and the inner edge of said flange is grooved for the reception of the upper clamp member 108. The lower member of said clamp consists of a knee-piece 109 vertically adjustable upon a bracket 110 mounted upon a cross-piece 111 carried upon the ways of the bed C. The knee-piece 109 is adjusted vertically by means of a screw 112 carried by the bracket 110, the head of which engages with the lower end of said knee-piece. The vertical member of said knee-piece 109 carries a vertically movable bolt 113 adapted, when projected, to enter the spaces 117 in the flange of plate 100, and thereby determine the horizontal position of the work relative to the tool. Said bolt 113 is provided with a horizontal projection 114 which engages at its free end with a cam-slot 115 in the head of the clamping bolt 116 so that, as the said bolt 116 is rotated to release the clamping members 108 and 109, the bolt 113 will be lowered to permit the work table 100 to be rotated to bring it in position for the engagement of said bolt 113 with the next recess 117, when the clamping bolt 116 is again turned to raise said bolt 113 and to clamp the flange 101 between the upper and lower clamping members 108 and 109. By means of the screw 110[a] the bracket 110 can be adjusted laterally on the member 111 to aline the parts carried by it with the coöperating parts of the support D.

By the arrangement of parts as above described and with the head cams 22 and 29 as shown in the drawings, the tool is caused to describe the path indicated in Fig. 13 and is at the same time maintained in such position that its cutting face is substantially at right angles to its path at all times, so that there is no tendency for the same to crowd or for one portion of the cutting face to lag behind the other. It is apparent that by varying the shape of the cams 22 and 29, the tool can be made to describe differently shaped paths and at the same time be positioned substantially at right angles to the same throughout its travel.

From an inspection of Fig. 12 it will be seen that the tool cuts a sinuous or irregular passage as the disk 9 is continuously rotated in one direction under the action of the shaft 44. The path of the tool is at right angles to the plane of the wheel blank, and without some special device for moving the tool out of its normal path on the return or idle portion of the stroke, the back of the tool would strike the blank and prevent further cutting. To obviate this, the crown cam 33 comes into operation just after the tool makes its cut in the blank, and the tool holder or spindle 8 is moved backward an amount sufficient to withdraw the tool from the cut and cause it to clear the blank. Continued rotation of the shaft 44 causes the tool to pass from the under to the upper side of the wheel blank, and after this movement takes place the crown cam comes into action and moves the tool into an operative position. The action of the feed mechanism is independent of the action of the crown cam, the latter coming into play once for each cutting movement of the tool.

In machines of the character described it is desirable to provide means for feeding oil to the cutting tool. In the present embodiment of my invention an oil pump 120 is provided (Fig. 8) having the usual suction and delivery valves. From the delivery valve or port a pipe, not shown, is arranged to carry oil and discharge it upon the tool. To actuate the pump a lever 121 is provided which is pivoted at one side of the head E to a support while the other end is connected directly to the pump piston. The lever is provided with a roller which engages with the cam 122 carried by the gear 42. The action of the cam is opposed by a compression spring which raises the piston and holds the roller in engagement with the cam.

The work-holder is normally fixed in position, and presents the disk, ring or segment thereof edgewise to the cutting tool. The tool is arranged to enter the blank obliquely from one side and leave it on the other side. In the present illustration the work is horizontal, but obviously it could be placed vertically if desired. Between the oppositely extending oblique portions of the passage is a curved portion the walls of which are concentrically curved. The walls of the ends of the buckets are flat and these flat walls or surfaces are tangentially arranged with respect to the curved walls of the central or intermediate portion of the passage. The passages are formed by successive cuts, and between cuts the tool and work are moved or fed relatively to each other.

In Fig. 11 is shown a tool 123 which I have found to be very satisfactory in cutting the sinuous passages in the wheel blanks. I do not however claim this, as it is the invention of another.

My invention is capable of many changes

and modifications, and I therefore do not limit myself to the particular embodiment of it herein shown and described.

What I claim as new and desire to secure by Letters Patent of the United States, is—

1. In a machine of the character described, the combination of a tool-holder, a support for the holder, which is movable about an axis, means for moving the holder radially toward and away from the axis of the support, a means for turning the tool-holder about its own axis while moving with the support, and means for moving the tool-holder longitudinally to withdraw the tool from cutting engagement with the work on the idle or return stroke.

2. In a machine of the character described, the combination of a tool-holder, a rotary carrier in which the holder is journaled, a disk having transverse guide-ways adapted to receive the carrier, means for moving the carrier laterally on the guide-ways when the disk is rotated, and means for oscillating the tool-holder about its axis.

3. In a machine of the character described, the combination of a tool-holder, a rotary carrier in which the holder is journaled, a disk having transverse guide-ways adapted to receive the carrier, means for moving the carrier laterally as it revolves, means for oscillating the tool-holder about its axis to maintain the tool normal to the cut, and means for moving the tool longitudinally to withdraw it from cutting engagement with the work on the idle or return stroke.

4. In a machine of the character described, the combination of a tubular shaft, means for rotating the shaft, a disk on the shaft having transverse guide-ways, a carrier mounted in the guide-ways, a spring acting on the carrier, a tool-holder mounted in the carrier, a cam adapted to move the carrier laterally on the guide-ways and against the spring as the shaft rotates, and means for oscillating the tool-holder about its axis to maintain the tool normal to the cut.

5. In a machine of the character described, the combination of an oscillating tool-holder, a tubular shaft, means for rotating the shaft, a carrier for the tool-holder, which is mounted within the shaft, a cam for moving the carrier laterally with respect to the axis of the shaft, gearing for oscillating the tool-holder about its axis, and a cam for actuating the gearing as the tubular shaft revolves.

6. In a machine of the character described, the combination of a tool holder, a work holder that presents the work edge on to the tool and also serves as a pivot therefor, a means for moving the tool holder angularly and at the same time guiding it in a manner to cause the tool to pass through the edge of the work from side to side on each cutting stroke, means for gradually turning the tool as it passes through the work to hold the same normal to the cut, and means which longitudinally retract the tool after it has passed through the work to cause it to clear the same on its return or idle stroke, and subsequently advance the tool into cutting position.

7. In a machine of the character described, the combination of a tool-holder, a rotary member which carries the tool-holder and tends to move it in the arc of a circle, a means for modifying the action of said member on the holder and causing the tool to enter the work tangentially, follow the path of a curve in the central portion of the work, and leave tangentially to the curved portion, means for oscillating the tool-holder about its axis to maintain the tool normal to the cut while the holder as a whole rotates with said member, and a device for moving the tool-holder longitudinally so that it will clear the work at a point beyond the cut and for advancing it into cutting relation after the work has been cleared.

8. In a machine of the character described, the combination of a tool-holder, a tubular shaft which surrounds the holder, a carrier for the tool-holder, which is supported by the shaft, guides movable with the shaft and engaging the carrier, a slotted disk located at one end of the tool-carrier and acting as a guide therefor, a cam feathered on the shaft, a means coacting with the cam for retracting and advancing the tool-holder, and a means for moving the carrier laterally on its guides as the shaft rotates.

9. In a machine of the character described, the combination of a work-holder, a tool-holder, a means for continuously rotating the tool-holder while the work-holder remains stationary, means for advancing and retracting the tool-holder during each rotation, and means causing the work- and tool-holders to approach each other as the operation of cutting progresses.

10. In a machine of the character described, the combination of a work-holder which presents the work edgewise to the tool, a tool-holder, a carrier for the tool-holder, a means for continuously rotating the carrier in one direction, means for causing the path of the tool to vary from a true circle so that it can enter and leave the work in a substantially straight line, means for causing the tool to be maintained normal to the cut while the carrier is rotated, a cam for advancing and retracting the tool-holder during each rotation of the carrier, and means for feeding the tool-holder toward the work during the idle portion of each stroke.

11. In a machine of the character described, the combination of a work-holder, a tool-holder, a carrier for the tool-holder, which is movable about an axis, a means for moving the tool-holder about its axis, a means for causing the path of the tool to vary from the arc of a circle so that it can enter and leave the work in a substantially straight line, and means for moving the tool-holder longitudinally during the idle portion of its stroke.

12. In a machine of the character described, the combination of a tool-holder, a work-holder which presents the work edgewise to the tool, a rotatable support for the tool-holder, means acting on the tool-holder to cause the tool to vary its path from a true circle as the support rotates, means for causing the tool-holder to move longitudinally away from the work between cutting strokes, means for maintaining the tool normal to the cut, and automatic feeding mechanism for advancing the tool as the cutting progresses.

13. In a machine of the character described, the combination of a fixed work-holder which presents the work edgewise to the tool, a tool-holder, a carrier therefor, means for rotating the carrier, a cam for moving the holder toward and away from the work for each revolution of the carrier, a carriage upon which the tool-holder, carrier and cam are mounted, and a feeding mechanism for advancing the carriage toward the work support as the cutting progresses.

14. In a machine of the character described, the combination of a tubular shaft, a means for rotating the shaft, a tool-holder mounted within the shaft, automatic means for moving the holder laterally with respect to the axis of the shaft as the latter rotates, a cam feathered on the shaft, which is attached to the holder, and rollers arranged to engage with the cam for reciprocating the holder.

15. In a machine of the character described, the combination of a tubular shaft, means for rotating the shaft, a tool-holder mounted in the shaft, guides for the holder, supported by the shaft, a crown cam which is feathered on the shaft, a rigid connection between the holder and cam, a carriage which supports the shaft, and rollers mounted on the carriage for reciprocating the cam on the shaft as the latter revolves.

16. In a machine of the character described, the combination of a shaft, a means for moving it, a tool-support slidably mounted in transverse guides on one end of the shaft, a cam, connections between the cam and tool support for oscillating the latter as it moves with the shaft, a second cam and connections therefrom to the tool-support for moving it laterally toward and away from the shaft axis, and a third cam and connections therefrom to the tool support for moving the latter longitudinally.

17. In a machine of the character described, the combination of a bed, a carriage mounted on and guided by the bed, a feed-screw for moving the carriage on the bed, a shaft mounted in the carriage, a tool-holder which is supported by the carriage and rotated by the shaft, a cam which surrounds the shaft and is mounted on the carriage, a connection between the cam and the tool-holder for maintaining the tool normal to the cut while the holder rotates with the shaft, a second cam which also surrounds the shaft and is supported by the carriage, and a connection between the second cam and the tool-holder for moving the tool-holder toward and away from the axis of the shaft for causing the path of the tool to vary from a true circle.

18. In a machine of the character described, the combination of a rotary member, a tool-holder supported thereby, means for moving the holder radially with respect to the axis of the rotary member as the latter revolves, and mechanism for oscillating the holder to keep the tool normal to the cut, comprising a pinion attached to the holder, a rack carried by the said member and meshing with the pinion, and a cam for actuating the rack.

19. In a machine of the character described, the combination of a tubular shaft, a tool-holder mounted within the shaft, a pinion which is secured to the holder for oscillating it so as to keep the tool normal to the cut, a rack for moving the pinion, which passes transversely through the shaft and is movable therewith, and a cam exterior to the shaft, which actuates the rack.

20. In a machine of the character described, the combination of a tubular shaft, a carrier mounted therein, guides for opposite ends of the carrier, which are supported by the shaft, a tool-holder mounted in the carrier, and means for moving the carrier and tool-holder radially with respect to the axis of the shaft as the latter revolves.

21. In a machine of the character described, the combination of a tool, a tool-holder, a work-holder which presents the surface of the work to be cut edgewise to the tool, a member which supports the tool-holder and moves about an axis, a means causing the path of the tool to vary from a given arc to one of greater radius as it passes through the work, a means for moving said member about its axis, and a means for separating the tool and work during the idle portion of the stroke so that the tool will clear the work.

22. In a machine of the character described, the combination of a tool for cutting the slots by a succession of cuts, a tool-

holder, a work-holder, a carrier for the tool-holder, a means for imparting angular movement to the carrier, a means for causing the path of the tool to vary from a true circle so that it may enter and leave the work on a path of large radius and to travel in a curved path while passing through the center portion of the work, and a means for moving the tool out of cutting relation and in a longitudinal direction on its idle or return stroke.

23. In a machine of the character described, the combination of a tool for cutting the slots by a succession of cuts, a tool-holder, a work-holder which presents the surface of the work to be cut edgewise to the tool, means causing the tool to cut the work and imparting a relative angular movement to the tool- and work-holders, a means for causing the path of the tool to vary from a true circle by moving the holders relative to each other during this angular movement in a direction transverse to the slot being cut, the said means being constructed and arranged to cause the tool to enter and leave the work on a path of large radius and to follow a curved path of different radius while passing through the center portion of the work, and a means acting automatically to withdraw the tool longitudinally from cutting engagement with the work on the idle or return stroke.

24. In a machine of the character described, the combination of a tool for cutting each slot by a succession of cuts, a tool-holder, a support for the tool-holder, a work-holder which presents the surface to be cut edgewise to the tool, means causing the tool to cut the work and imparting a relative angular movement to the tool- and work-holders, means for moving the support and the work-holder relative to each other during said angular movement in a direction transverse to the slot being cut, said means being constructed and arranged to cause the tool to move in a curved path in the middle portion of the work and to leave the work tangentially with respect to the curved portion, and a means constructed and arranged to withdraw the tool longitudinally after it finishes its cutting stroke and hold it out of engagement during the return or idle stroke and finally to return the tool to a cutting position before it reënters the work.

25. The combination of a cutter and a work holder, means for feeding them toward each other as the cutting progresses, means for giving them a relative orbital movement in a plane at a right angle to the direction of feed, and means for causing one of them to advance and recede at different portions of the orbital path.

26. In a machine for cutting curved slots across a face of a ring or disk or segment thereof, the combination with a work holder which is stationary while the tool is cutting the work, of a moving cutting tool for producing a slot by a succession of cuts, means for giving such tool a cutting movement of varying radius, means for turning such tool axially during its cutting movement to keep it normal to the cut, and means for retracting the tool at the end of each cut and for advancing it just prior to its reëngagement with the work.

27. In a machine for cutting curved slots across a face of a ring or disk or segment thereof, the combination of a cutting tool for producing a slot by a succession of cuts, and a work holder, such tool and holder having a relative circular movement and engaging on one side of the circular path, with means for relatively retracting the tool from the work on the other side, and means for varying the path of movement of the tool in the work from a true circle.

28. In a machine for cutting curved slots across a face of a ring or disk or segment thereof, the combination of a cutting tool for producing a slot by a succession of cuts, and a work holder, such tool and holder having a relatively circular movement and engaging on one side of the circular path, with means for relatively retracting the tool from the work on the other side, means for varying the path of the tool in the work from a true circle, and means for keeping the tool normal to the cut.

29. In a machine for cutting curved slots across a face of a ring or disk or segment thereof, the combination of a cutting tool for producing a slot by a succession of cuts, and a work holder, such cutting tool being carried eccentrically by a rotating head, with means for moving such tool toward and away from the center around which it rotates to cause the tool to describe a path of varying curvature in the work, and means for turning the tool axially to keep it normal to the cut.

30. In a machine for cutting curved slots across a face of a ring or disk or segment thereof, the combination of a cutting tool for producing a slot by a succession of cuts, and a work holder, such cutting tool being carried eccentrically by a rotating head, with means for moving such tool toward and away from the center around which it rotates to cause the tool to describe a path of varying curvature in the work, means for turning the tool axially to keep it normal to the cut, and means for relatively retracting the tool and work to enable the tool to clear the work during part of its rotation.

31. In a machine for cutting curved slots across a face of a ring or disk or segment thereof, the combination with a cutting tool for producing a slot by a succession of cuts, and a work holder, of a rotating head, a

spindle mounted in bearings in said head and carrying the cutting tool, means for rocking said tool-carrying spindle axially to keep the tool normal to the cut, and means for giving said tool-carrying spindle a reciprocating motion in said head to clear the work during a part of its rotation.

32. In a slotting machine for cutting curved slots, the combination with a cutting tool mounted eccentrically upon a rotating head, and means for varying the path of the tool from a true circle, of an axial cam and connections between said cam and said cutting tool, whereby the cutting tool will be turned axially to maintain the tool normal to the cut.

33. In a slotting machine for cutting curved slots, the combination with a cutting tool mounted eccentrically upon a rotating head and carried by a shaft, of a pinion upon said tool-carrying shaft, a rack-bar engaging said pinion and revolving with said shaft, and a stationary cam with which said rack-bar engages for giving the tool-carrying shaft axial movements.

34. In a slotting machine for cutting curved slots, the combination with a cutting tool mounted eccentrically upon a rotating head, of a cam for retracting the cutting tool, so as to cause it to clear the work during a portion of its rotary motion.

35. In a slotting machine for cutting curved slots, the combination of a work-holder which presents the work edgewise to the tool, a tool holder, a carrier for the tool-holder, means for continuously rotating the carrier in one direction, means for moving the carrier to one side of its axis to cause the path of the tool to vary from a true circle so that it can enter and leave the work on a path of relatively large radius, means for rotating the tool holder in relation to the carrier to cause the tool to be maintained normal to the cut while the carrier is rotated, means for advancing and retracting the tool-holder during each rotation of the carrier, and means for feeding the tool-holder toward the work during the idle portion of each stroke.

In witness whereof I have hereunto set my hand this 24th day of January, 1902.

SHEPHERD T. FONDA.

Witnesses:
BENJAMIN B. HULL,
FRED RUSS.