H. GEISENHÖNER.

MACHINE FOR CUTTING TURBINE VANES OR BUCKETS.

APPLICATION FILED JAN. 27, 1902.

972,848. **Patented Oct. 18, 1910.**

3 SHEETS—SHEET 1.

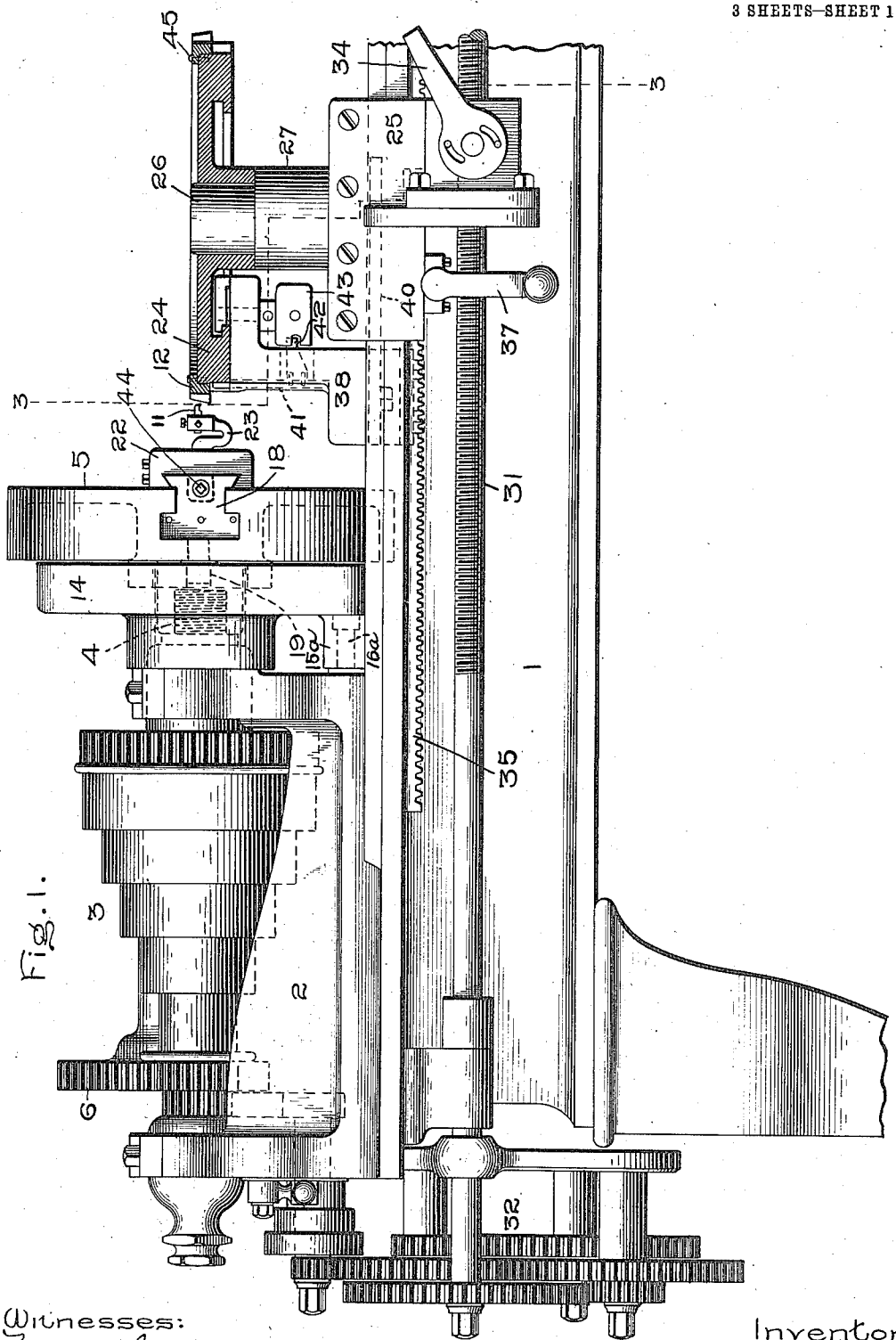

Fig. 1.

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3 SHEETS—SHEET 2.

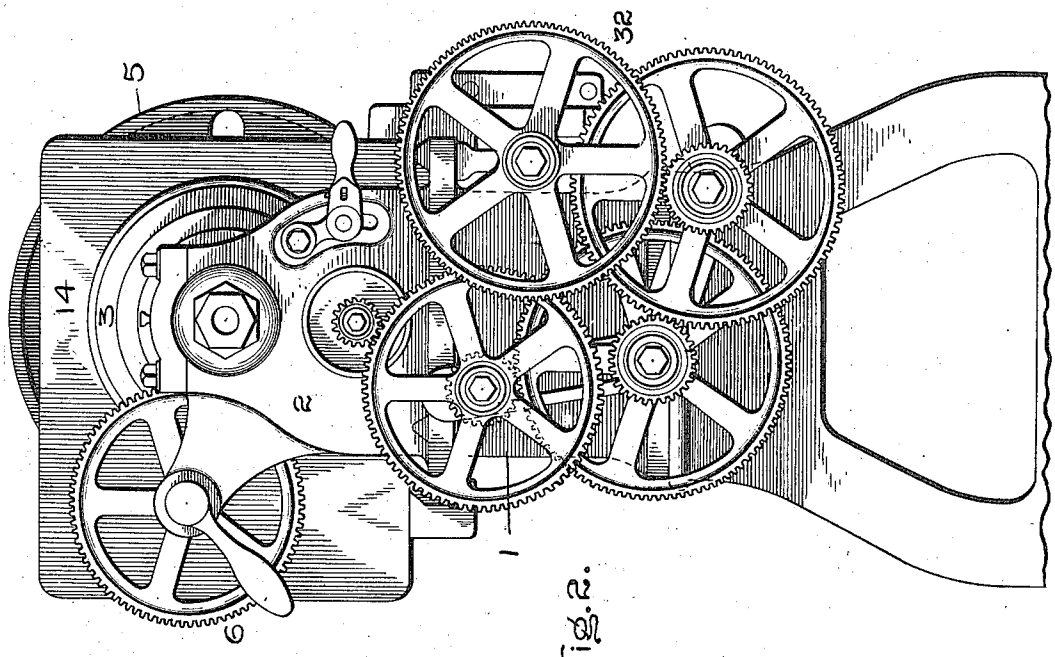

Fig. 2.

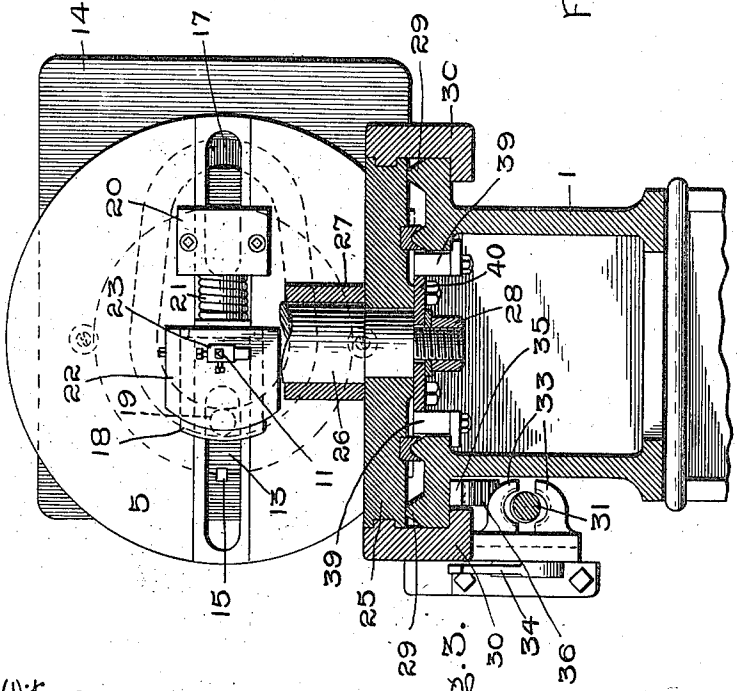

Fig. 3.

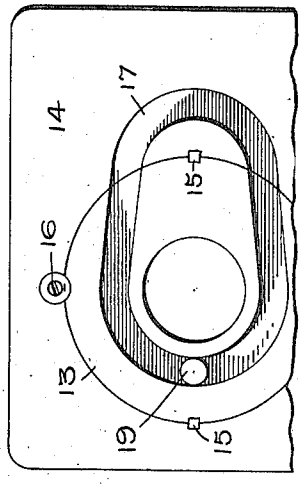

Fig. 4.

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3 SHEETS—SHEET 3.

Fig. 5.

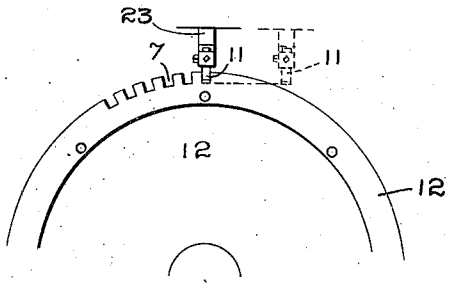


Fig. 6.

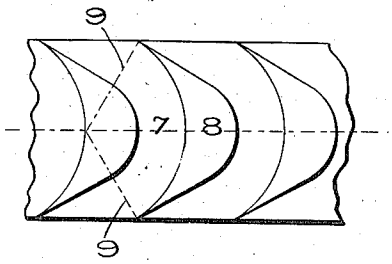


Fig. 7.

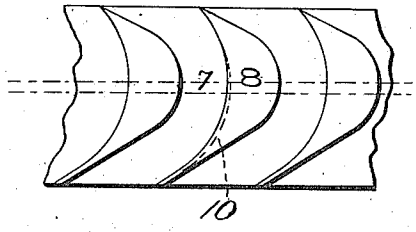


Fig. 8.

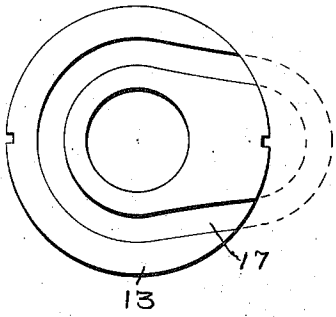
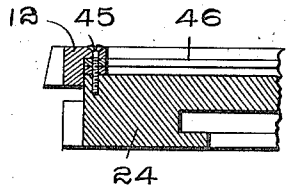


Fig. 9.



Witnesses:
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UNITED STATES PATENT OFFICE.

HENRY GEISENHÖNER, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

MACHINE FOR CUTTING TURBINE VANES OR BUCKETS.

972,848. Specification of Letters Patent. Patented Oct. 18, 1910.

Application filed January 27, 1902. Serial No. 91,329.

To all whom it may concern:

Be it known that I, HENRY GEISENHÖNER, 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 Vanes or Buckets, of which the following is a specification.

Steam or other elastic fluid turbines as commonly constructed are provided with one or more revolving members each of which is provided with a circular row of vanes or buckets formed integral therewith. These vanes are of such shape and are so arranged that the elastic fluid leaving the nozzle will impinge thereon and produce rotation. When two or more rows of wheel buckets are provided for each stage, it is necessary to provide intermediate buckets which may be stationary or rotary as desired, and these buckets receive motive fluid from one set of wheel buckets and discharge it at the proper angle against the adjacent set or sets of wheel buckets. In order to produce an efficient turbine, it is necessary to form these vanes with great care and accuracy. In certain instances these vanes are so constructed that the spaces or sinuous passages between them increase in size toward the exhaust end of the machine by an amount which is just sufficient to compensate for the increased volume of the motive fluid. In certain other instances the vanes are so constructed that the spaces or passages between them enlarge toward the exhaust by an amount which is sufficient to convert an appreciable amount of steam pressure into *vis viva*. It will be seen from the foregoing that the greatest accuracy is involved in obtaining the best results.

My invention has for its object to produce a machine which will cut the vanes accurately with a minimum expenditure of time and labor; and this without requiring workmen of more than average skill.

My invention further has for its object to produce a machine which can, by simple changes, be arranged to cut vanes on wheels of largely varying diameters and different widths.

The scope of the invention will be more fully described and claimed hereinafter.

In the accompanying drawings, which illustrate an embodiment of my invention, Figure 1 is a side elevation of the machine; Fig. 2 is an end view of the same; Fig. 3 is a cross-section of the machine taken on line 3—3 of Fig. 1 looking toward the cutting tool; Fig. 4 is a detail view in elevation of the cam for changing the path of the tool; Fig. 5 is a diagrammatic view showing the path of the cutting tool; Fig. 6 is a plan view illustrating the shape of the vanes cut in the turbine wheel; Fig. 7 is also a plan view of the vanes showing the cutting center displaced somewhat from the center of the wheel blank; Fig. 8 is a view in elevation of the detachable portion of the cam; and Fig. 9 is a sectional view showing the means employed to adjust the positions of the wheel blank on its support.

In the drawings I have shown my improved vane- or bucket-cutting mechanism applied to a lathe, but it is evident that it can be used in connection with other kinds of apparatus, either those especially designed or otherwise.

1 represents the bed of the lathe having the usual guides or ways, and mounted on the left hand end is a head 2. The cone pulleys 3 are mounted on a driving spindle in the usual manner, the said spindle being provided with a screw-threaded end 4 to which is secured the revolving tool carrying head 5. The lathe is provided with the usual back gearing 6 which may or may not be used in cutting vanes as desired. One advantage of the construction illustrated is that it can be applied and removed from an ordinary lathe without in any way destroying its usefulness for ordinary purposes.

The vanes are preferably cut out of solid stock, and in the present instance are of the shape shown in Figs. 6 and 7, although the particular configuration can be varied without departing from the spirit of my invention. In Fig. 6 the center of movement of the tool is coincident with a plane passing through the center of the blank, indicated in dotted lines. The sinuous passage 7 is of the same width throughout, consequently the vane 8 is narrower at the edges than in the center. The portions of the side walls of the vanes between the dotted lines 9 are concentric, while the remainder of the walls are straight. The depth of the passage may be the same throughout, or it may increase in depth by a greater or less amount by making the peripheral surface of the wheel a frustum of a cone instead of a cylinder.

This feature is indicated in Fig. 1. Under ordinary conditions the cross-sectional area of each passage increases slightly from the receiving toward the discharge end in order to compensate for the decreased velocity of the elastic fluid and to compensate for frictional retardation.

In Fig. 7 the centers of the arcs on which the vanes are cut are displaced with respect to a plane passing through the center of the blank, as is indicated by the broken-and-dotted line. This means that the shape of the vanes is slightly altered. If it is desired to modify the shape of the passage, as for example by increasing the width of the passage 7 at one end instead of arranging it as shown, the blank is first cut with grooves or passages having parallel sides, as in Fig. 6. The blank is then raised with respect to the cutting tool and the operation of cutting is repeated. When this is done portions of the vanes 8 will be cut away, as indicated by dotted line 10, thus increasing the clearance on one side of the wheel, preferably the exhaust.

The path of the cutting tool while in the act of cutting or forming the buckets follows a path of varying radius; that is to say, for a portion of its stroke the tool moves in the arc of a circle, and for the remainder of its stroke the radial distance between the tool and the axis of the driving spindle gradually increases. This is made plain from Fig. 6, wherein the dotted lines 9 indicate the points where the circular portion of the path ceases, and the path of increasing radius begins. In the present instance the cylindrical portion or surface of the vane or bucket merges into a plane surface which is tangentially arranged with respect thereto.

In so far as the broader aspects of the present invention are concerned, the ends of the buckets may be curved or straight, although certain advantages are found in making them straight. In either case the buckets are made thicker at the middle than at the ends, and have sharpened edges; the latter feature adds greatly to the efficiency of a turbine, hence the importance of having a machine which will accurately cut the buckets.

In cutting the vanes the tool 11 is rotated and travels for a major portion of its stroke in the path of a circle while moving from one side of the wheel blank to the other. In the present machine the tool 11 moves from the top to the bottom of the blank or vane-carrying wheel 12; in other words, in a plane at right angles to that of the wheel blank. The motion of the tool being continuous and due to the rotation of the head 5, it is necessary to provide some means for moving the tool in a manner to clear the periphery of the wheel blank 12 on the return or idle portion of its stroke. The means for imparting this orbital motion to the tool will be apparent by referring to Fig. 5, wherein 7 represents the passages formed in the blank, and 11 the tool shown in the act of cutting one of the passages. After the tool finishes its cut, it is moved under the blank to the position indicated by the dotted lines, after which it moves upward and across the top of the blank, and again passes down through the passage 7 until the latter is cut to the desired depth. After one of the passages is completed, the blank is advanced an angular distance equal to one vane, and the same operation is repeated. In order to impart the necessary movement to the tool to cut the stock and clear the blank on the return stroke, a special cam is provided which is formed partly in the detachable piece 13 (Fig. 4), and partially in the stationary support 14. The support is provided with a hub-like projection which engages with the head of the lathe, and formed on the back thereof are projections 15^a which also engage with the stationary head of the lathe. Passing through the projections are retaining bolts 16^a, the said projections being counter-bored to receive the heads of the bolts. The support 14 is provided with a large circular opening to receive the detachable cam 13, the latter having a cam-groove 17, of suitable configuration. The object in making this portion of the cam detachable is to provide means for cutting blanks of different sizes, or of the same size with different vane shapes, or both. By reason of this arrangement a number of cams can be provided at a small expense, suitable for cutting different wheels, and inserted in place in the head, and this with a small expenditure of labor. The cam is retained in place by the keys 15 and the screws 16, the latter being provided with washers that extend over the edge of the cam. Formed in the stationary support is a cam-groove which coincides with the groove 17 formed in the detachable portion 13. The total distance between the ends of the cam-groove thus formed is sufficient to move the tool 11 out of engagement with the blank on the return stroke. It is evident that for some blanks the movement will be rather more than is necessary, while in others it will be just enough; but the saving in the use of a single support 14 is great enough to compensate for this slight loss. For larger or smaller machines the length of the groove will be varied to suit the given conditions, but in any event it should be great enough to cause the tool to clear the blank on the idle or return portion of its stroke. The portion of the cam-groove 17 which directs the cutting tool through the blank is concentric with the center of movement, but its shape can be altered to suit any given condition.

Mounted in a slot in the revolving head 5

is a slide 18 which is provided on the back side with a pin and roller 19 (Figs. 3 and 4), the latter traveling in the cam path 17, and as the head 5 is rotated this slide is moved toward and away from the center of revolution. Mounted on the rotating head is a stationary abutment 20, and between this abutment and the slide 18 is a compression spring 21 which tends at all times to force the cam-roller 19 against the outer edge of the cam-groove. Adjustably mounted on the slide 18 is a support 22 which carries the tool holder 23. On the back of the support 22 is a projection, shown in dotted lines in Fig. 1, and this projection is provided with a screw-threaded opening for receiving the adjusting screw 44. The tool holder should have a certain amount of spring in order to prevent the tool from breaking in event of its meeting an unusual obstruction as it passes through the blank. This spring support is attained in the present case by making the holder U-shaped. From the foregoing it will be seen that the tool has a fixed plane of movement while it is moved toward and away from the center of movement of the spindle 4 by the stationary cam.

In Fig. 8 is shown a cam having a cam groove which is slightly larger in diameter than the one shown in the other figures. It will be seen that the portions connecting the curved ends have been very slightly altered owing to the changed diameter of the larger end of the cam-groove.

The work-holder for supporting and moving the blank toward and away from the cutting tool will now be described. After the sides and periphery of the blank 12, which may be a disk, a plate or a ring, or segment thereof, have been machined, it is mounted on the rotatable support 24 which in turn is carried by the sliding carriage 25 through the medium of the stud 26, the arrangement being such that the work is presented edgewise to the cutting tool. The blank is retained in place on the support by suitable screws or clamps 45. The under side of the rotatable support is provided with a hub that rests on and is supported at a fixed vertical height by the sleeve 27. The sides of the stud 26 are straight and furnish a substantial bearing for the rotating support. The lower end of the stud is shouldered and is retained in place on the carriage by a nut 28. The carriage travels back and forth on guides or ways 29, and is prevented from lifting and twisting by the L-shaped pieces 30, that engage with the projecting flange on the bed 1.

The support 24 consists essentially of a ring having a shoulder formed on the periphery, which shoulder preferably forms a working fit with the inner wall of the wheel blank 12, in order to prevent displacement under the action of the cutting tool. When it is desired to cut a blank which is thicker or of a different diameter, the ring can be removed and a different one substituted. When it is desired to make a second cut for the purpose of changing the shape of the expanding end of the passage, *i. e.*, the end toward the exhaust, the wheel may be raised to the desired position by placing a thin ring or rings between it and the support. In order to provide for blanks of varying thickness where only a single revolving support is provided, the shoulder may be made deep enough to receive the thickest blank designed to be cut on the machine, and shims made of rings employed to raise the thinner rings to the desired height. Such a construction is shown in Fig. 9, wherein 12 represents the blank, 24 the revolving support, 46 the shims, the latter being circular so as to afford a firm support for the blank at all points, and 45 the bolts that hold the blank and shims in place.

The automatic movements of the carriage toward and away from the cutting tool are controlled in the following manner. Mounted on the front of the bed in suitable bearings is a screw 31 of relatively low pitch which is driven by the spindle 4 through suitable speed reducing gearing 32. The carriage is connected to the screw by a pair of movable jaws 33 (Fig. 3), and these jaws are under the control of the handle 34. When the handle is in the raised position (Figs. 1 and 3), the jaws are disengaged from the screw, but when the handle is lowered, the jaws engage the screw and the movements of the carriage are controlled thereby. In order to move the carriage manually toward and away from the cutting tool, a rack 35 is secured to the under side of the front flange of the bed, and engaging therewith is a pinion 36 which is rotated by the handle 37 (Fig. 1). The manual control can be utilized only when the automatic feeding devices are disconnected from the carriage. The principal strain on the rotating support 24 is in a downward direction and at the point where the cutting tool 11 engages with the blank, and in order to furnish additional support therefor, a special or auxiliary supporting device is provided. In the present arrangement this support comprises a post 38 having at its upper end a projection which engages with the circular groove formed in the under side of the rotating support. The lower end of the post is enlarged, and rests on the inner guides or ways on the bed 1. The post is prevented from rising and twisting by the clamps 39, Fig. 3, that engage with the inner flanges on the bed. In order to insure corresponding movements of the post and rotating support, a plate 40 is bolted to the under side of the post and is clamped to

the carriage by the nut 28, which holds the stud 26 in place. The post and carriage are shown as being made of separate pieces and bolted together, but it is obvious that they may be made in a single piece.

In order to insure that the vanes on the turbine wheel shall be accurately spaced, the rotating support 24 is provided with a number of notches, the number of notches being equal to the number of vanes on the wheel or segment thereof. In other words the support also forms an index wheel. Mounted on the post for engagement with the notches is a sliding piece 41 shown in dotted lines in Fig. 1. Extending laterally from said piece is a projection 42 that enters a cam-groove formed in the rotating head 43. The head is provided with a bearing in the post and is rotated by means of a pin or similar device which can be inserted in the holes formed therein. The support 24 and the blank are rotated by hand until one of the notches in the index wheel coincides with the sliding piece 41, after which the head 42 is rotated in a manner to move said piece upward and lock the parts in place.

In the present instance the turbine wheel blank is horizontally supported on the machine, but where the wheels are large they may be mounted vertically, in which case the cam-groove 17 would have its greatest length at right angles to that shown, so that the tool will make its cut substantially at right angles to the one shown.

Assuming that a blank wheel of any suitable diameter is mounted on its rotating support and the carriage connected to the screw: power is then applied to the driving spindle 4 which causes the head 5 to rotate continuously and carry with it the tool 11 and the screw 31 feeds the carriage forward. As the head rotates the roller 19 carried by the support 18 travels in the cam-groove 17 and causes the support 22, tool support 23 and tool 11, to move toward and away from the center of rotation of the spindle 4, thereby following a path of varying radius. When the roller is moving in that part of the cam-groove which is concentric with the center of movement of the head, the tool 11 will be cutting the curved portion of the passage in the blank, but as soon as it reaches a non-concentric point, the lateral movement of the tool, arranged to keep the tool out of engagement with the blank, commences. The straight portions of the vanes are cut when the cam roller is passing from the concentric to the non-concentric portion of the cam groove. It will be seen that the tool has two motions, first an orbital motion due to the cam 13, which causes it to move toward and away from the axis of rotation of the driving spindle, and, second, a rotating motion due to the rotation of the spindle. It is by a combination of these two motions that the flattened ends of the buckets are produced. The tool enters the work obliquely and moves forward in a straight line until it reaches the point indicated by the dotted line 9, when it changes to a curve and continues to the second dotted line 9, after which the path becomes straight again and the tool leaves the work obliquely, but the leaving angle is opposite the entering angle. As soon as the roller reaches the extreme right-hand portion of the cam-groove, the tool starts back, and when the proper point is reached it will again turn downward and pass through the blank and again cut away a certain amount of metal. As the cutting proceeds by successive steps, the carriage and blank are automatically fed forward until the desired depth of groove is attained, after which the carriage is disconnected from the screw, moved backward by hand and the blank adjusted to a new position and the action repeated.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention, together with the apparatus which I now believe to represent the best embodiment thereof; but I desire to have it understood that the apparatus shown is only illustrative, and that the invention can be carried out by other means.

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 work-holder which presents the surface of the work to be cut edgewise to the tool, a tool for forming the slots by successive cuts, a tool-holder, a means for rotating the tool-holder, and a means for imparting an orbital motion to the tool-holder, the tool being arranged to pass through the work in the direction of the width of the bucket, whereby it is maintained out of engagement with the work during a part of each revolution.

2. In a machine of the character described, the combination of a work-holder which presents the work edgewise to the tool, a tool for forming the passages by successive cuts across the peripheral face of the blank, a tool-holder, the axes of the work- and tool-holders being located in planes substantially at right angles to each other, means for continuously rotating the tool-holder in one direction, thereby causing it to pass through the peripheral face of the blank, and means for moving the tool and its holder laterally with respect to the work during the idle portion of its stroke so as to clear the work and return to an operative position.

3. In a machine of the character described, the combination of a tool for forming the passages by a succession of cuts, a tool-holder, a shaft for rotating the tool-holder,

a support which holds the blank in a plane at right angles, or substantially so, to the path of movement of the tool-holder, and a cam which imparts an orbital motion to the tool-holder at substantially right angles to the plane of the work so that the tool will clear the work during a portion of its stroke.

4. In a machine for cutting curved slots in the edge of metal blanks, the combination of a tool arranged to form the passages by successive cuts from one side of the blank to the other, a tool-holder, a revolving head upon which the tool-holder is mounted in a manner to have independent movement, a cam for moving the tool across the edge of the blank and also for moving the tool-holder toward and away from the center of revolution of the head, a rotatable support which presents the blank edgewise to the tool and at right angles to the tool, or substantially so, and means for locking said support while the tool is cutting.

5. In a machine of the character described, the combination of a tool, a tool-holder, a pivotally supported head which carries the holder, a cam for causing the path of the tool to vary from a true circle, said cam constructed and arranged to cause the tool to enter and leave the work on a path of large radius and to travel in a path of different curvature while passing through the center portion of the work, a work-holder which supports the work in a plane substantially at right angles to that of the tool and presents the blank edgewise to the tool, and means for feeding the tool and work-holder with respect to each other.

6. In a machine of the character described, the combination of a driving spindle, a head mounted on the spindle, a tool-holder mounted on the head and eccentrically disposed with respect to its axis, a cam for causing the path of the tool to vary from a true circle, said cam constructed and arranged to cause the tool to enter and leave the work on a path of large radius and to travel in a path of smaller curvature while passing through the center portion of the work, a stationary abutment on the head, a spring engaging the abutment for forcing the holder into engagement with the cam surface, and a work-holder which presents the work edgewise to the cutting tool.

7. In a machine of the character described, the combination of a driving spindle, a tool driven by the spindle and eccentrically mounted with respect to its axis, a means for causing the path of the tool to vary from a true circle, said means constructed and arranged to cause the tool to enter and leave the work on a path of large radius and to travel in a path of smaller curvature while passing through the center portion of the work, a carriage for supporting the work, a means for moving the carriage toward and away from the tool, and automatic means for feeding the tool and carriage with respect to each other.

8. In a machine of the character described, the combination of a tool, a revolving head, a tool-holder carried by the head, a means for causing the path of the tool to vary from a true circle, said means constructed and arranged to cause the tool to enter and leave the work on a path of large radius and to travel in a curved path of smaller radius while passing through the center portion of the work, a work-holder which presents the work edgewise to the tool, a carriage for moving the work-holder, automatic mechanism for feeding the carriage and work with respect to each other, and means for throwing the mechanism into and out of action.

9. In a machine of the character described, the combination of a rotary tool-holder, a work-holder, the axes of said holders lying substantially at right angles to each other, a cutting tool mounted in the tool-holder, means for imparting angular movement to the tool-holder, means for causing the path of the tool to vary from a true circle, said means constructed and arranged to cause the tool to enter and leave the work on a path of large radius and to travel in a path of smaller curvature while passing through the center portion of the work, and means for guiding the tool and tool-holder in their movements toward and away from their axis of movement.

10. In a machine of the character described, the combination of a cutting tool, a holder therefor, means for moving said tool-holder about a given axis, means for causing the path of the tool to vary from a true circle, said means constructed and arranged to cause the tool to enter and leave the work on a path of large radius and to travel in a curved path of smaller radius while passing through the center portion of the work, guides for the tool-holder, a work-holder, and means for raising and lowering the work with respect to the center of movement of the tool.

11. In a machine of the character described, the combination of a tool, a spring holder for the tool, a head for supporting and moving the tool about a given axis, and a means for causing the path of the tool to vary from a true circle, said means constructed and arranged to cause the tool to enter and leave the work in a path of large radius and to travel in a curved path of different radius while passing through the center portion of the work.

12. In a machine of the character described, the combination of a tool, a rotatably mounted holder therefor, a driving means for imparting angular movement to the holder, a means for causing the path of

the tool to vary from a true circle, said means constructed and arranged to cause the tool to enter and leave the work on a path of large radius and to travel in a curved path of smaller radius while passing through the center portion of the work, a work-holder, and an auxiliary support for the work situated near the point of cutting.

13. In a machine of the character described, the combination of a rotatable work-holder, a rotary tool-holder, the axes of said holders lying substantially at right angles to each other, a cutting tool mounted in the tool-holder and eccentrically disposed with respect to the axis of rotation of the holder, means for rotating said tool-holder, and means for causing the path of the tool to vary from a true circle, said means constructed and arranged to cause the tool to enter and leave the work on a path of large radius and to travel in a path of smaller curvature while passing through the center portion of the work.

In witness whereof, I have hereunto set my hand this twenty-first day of January, 1902.

HENRY GEISENHÖNER.

Witnesses:

BENJAMIN B. HULL,

BERTHA SECOR.