April 24, 1928. 1,667,153

B. HEYMANN

MACHINE FOR PRODUCING IRREGULAR SURFACES

Filed Aug. 14, 1924 3 Sheets-Sheet 1

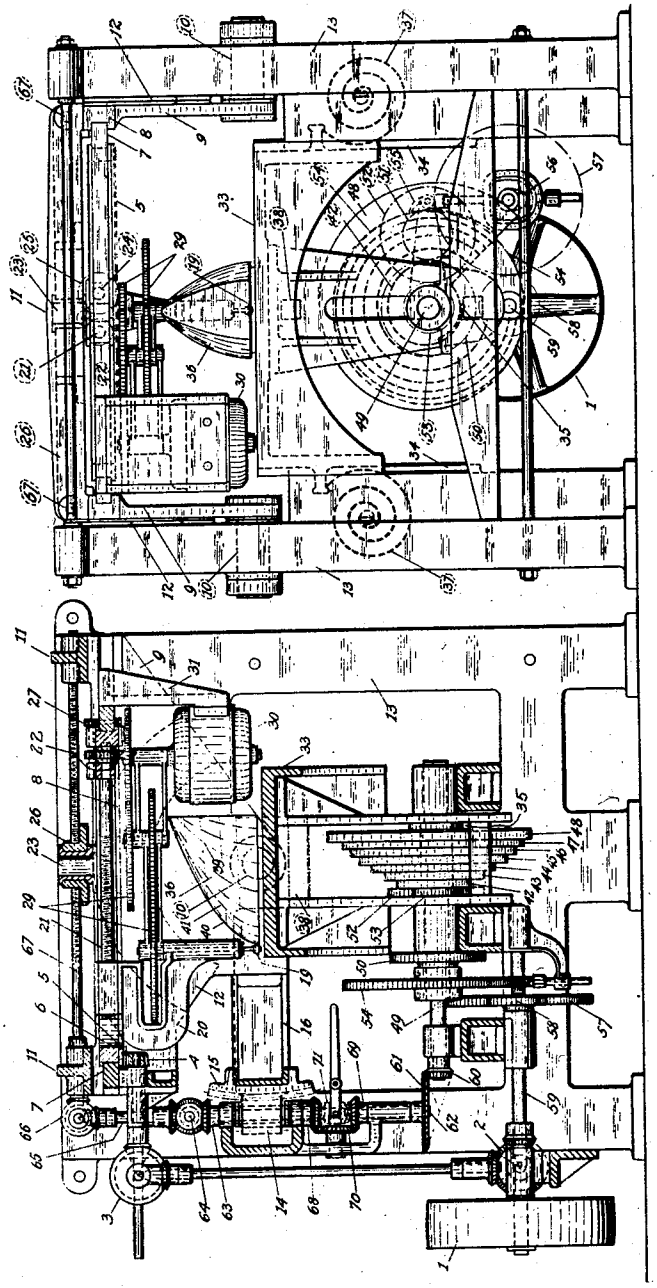


Fig. 2.

Fig. 1.

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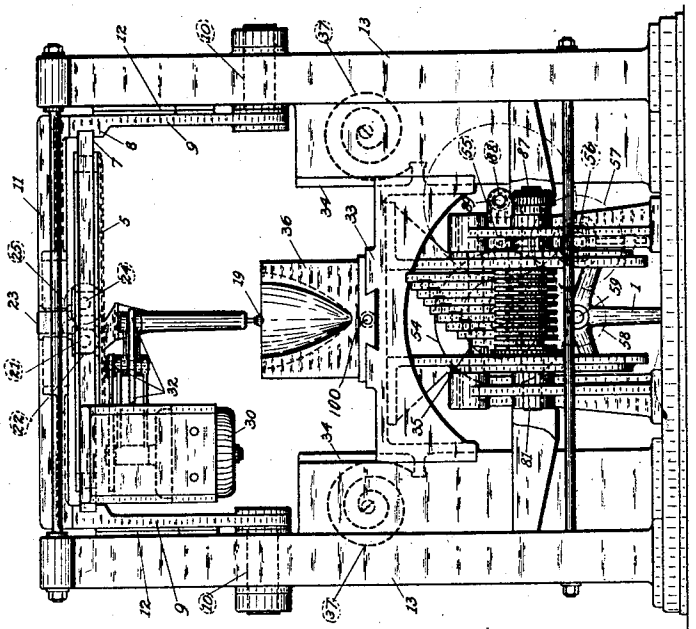


Fig. 4.

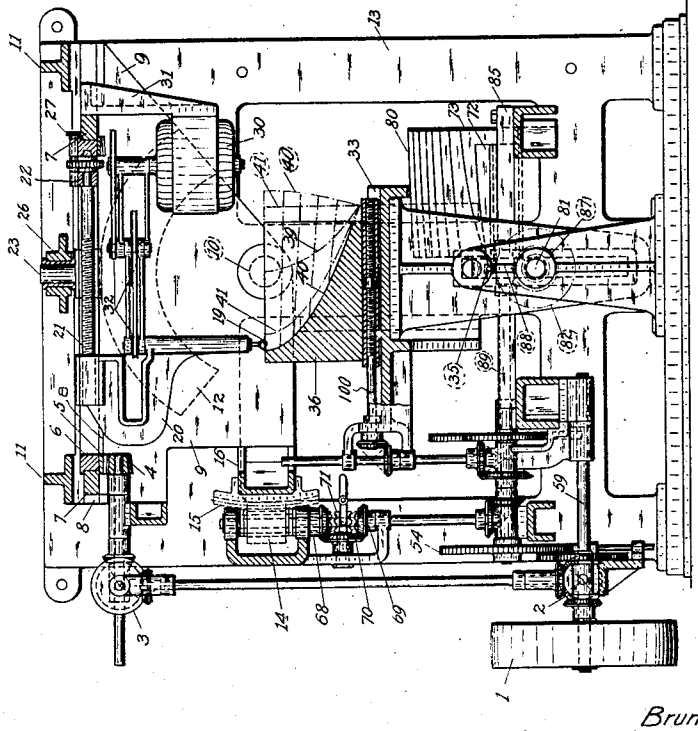


Fig. 3.

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Filed Aug. 14, 1924 3 Sheets-Sheet 3

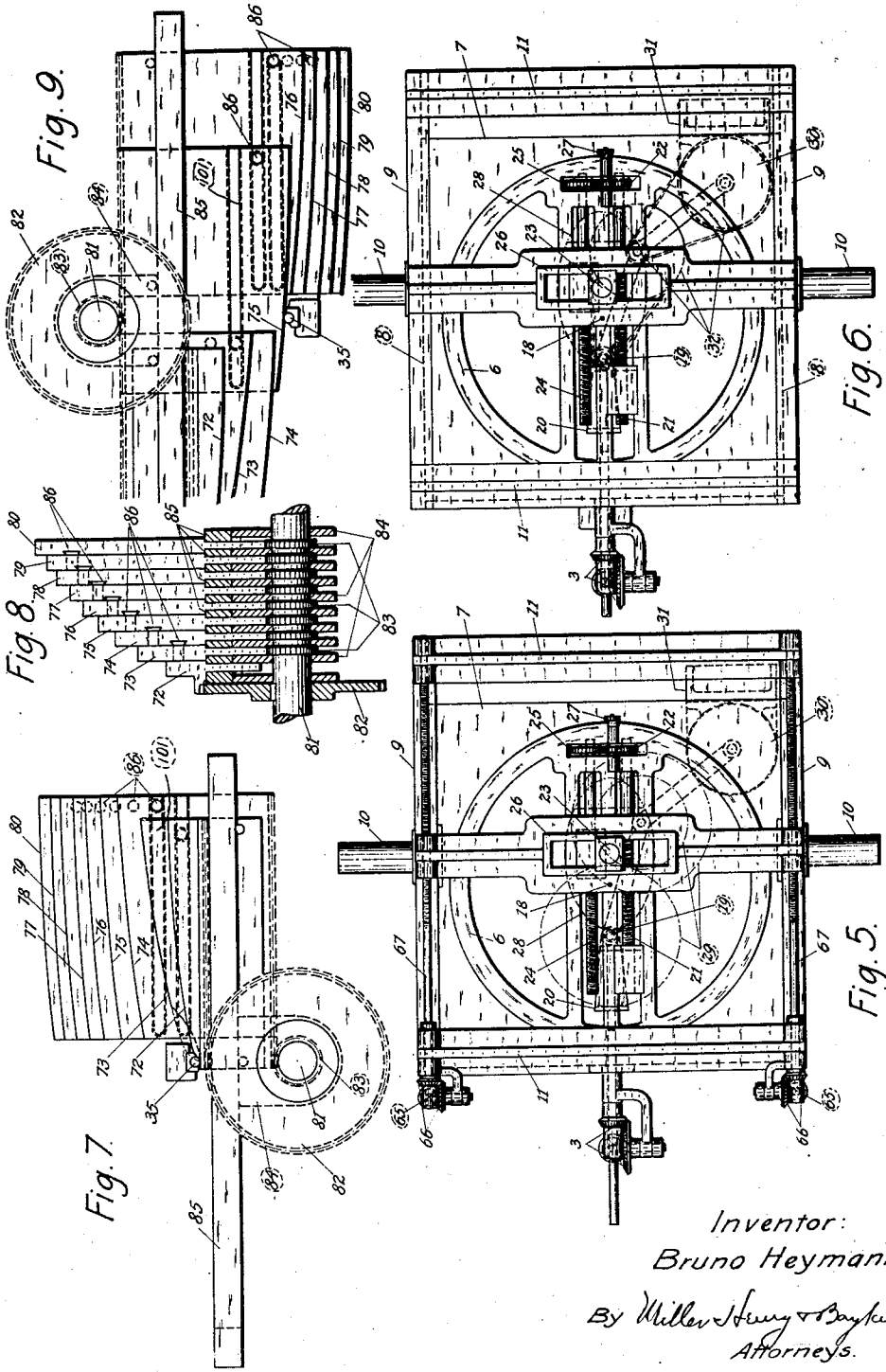


Fig. 9.

Fig. 6.

Fig. 8

Fig. 5.

Fig. 7

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Patented Apr. 24, 1928. 1,667,153

UNITED STATES PATENT OFFICE.

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MACHINE FOR PRODUCING IRREGULAR SURFACES.

Application filed August 14, 1924. Serial No. 732,475.

This invention is particularly adapted to a machine for the production of conicoids or quadrics of prescribed mathematical formulæ and which may be defined as:

A. A conicoid or quadric which is an envelope formed by a family of ellipsoids of revolution having variable parameters and a family of paraboloids of revolution having variable parameters, all of these two groups of surfaces having one focus in common, while the free foci of the ellipsoids of revolution have their locus on a straight line perpendicular to the principal horizontal plane through the ellipsoid of the greatest parameter. Or:

B. A conicoid or quadric which is an envelope first: of a family of ellipsoids of revolution having variable parameters and second: of a family of hyperboloids of revolution having variable parameters, all of these two groups of surfaces having one focus in common, while the free foci of the ellipsoids of revolution have their locus on a straight line perpendicular to the principal horizontal plane through the ellipsoid of the greatest parameter. Or:

C. A quadric or envelope surface formed of ellipses of variable parameters in a series of either horizontal parallel or horizontal diverging planes; and of either parabolic arcs of variable parameters or hyperbolic arcs of variable parameters in a vertical axial pencil of planes, the said axis being the locus of one of the foci of all horizontal or diverging ellipses, while the locus of the foci of all parabolic and hyperbolic arcs is a fourth degree curve, i. e. a limacon of Pascal.

My invention is also especially adapted for the production of punches and dies by which thin metal surfaces such as reflectors may readily be formed and wherein the surface varies in accordance with a formula involving variables of the second degree without being a surface of revolution and as particularly described above.

To produce such a surface, internally or externally, I establish the necessary relative movement between the tool and the surface as generated, by causing the tool to move progressively in horizontal parallel or horizontal diverging elliptical paths of varying sizes while causing the table with the material on which the tool is working to be moved intermittently upward or downward, and, at the same time establishing a relative horizontal or lateral movement between the table and tool; the combination of both these vertical and horizontal or vertical and lateral movements resulting in a parabolic or hyperbolic arc. These arcs are based on the loci of first: all the vertices, or second: all the foci, or third: all the centers of all horizontal parallel or horizontal diverging ellipses described by the tool, and all these movements are automatic and relatively properly timed.

By referring to the accompanying drawings my invention will be made clear.

Figure 1 shows a vertical longitudinal central section of the machine of my invention adapted to the production of punches.

Fig. 2 shows a front view of the machine of Fig. 1.

Fig. 3 shows a vertical longitudinal central section of the machine of my invention adapted to the production of dies.

Fig. 4 shows a front view of the machine of Fig. 3.

Fig. 5 shows a plan view of the oscillating frame and the elliptical cutting portions of the machine of Fig. 1.

Fig. 6 shows a plan view of the oscillating frame and elliptical grinding portions of the machine of Fig. 3.

Fig. 7 shows, in a larger scale, the nest of sliding cams arranged for the cutting or grinding of dies.

Fig. 8 shows a front view of the sliding cams of Fig. 7.

Fig. 9 shows, in larger scale, the nest of sliding cams arranged for the cutting or grinding of punches.

Throughout the figures similar numerals refer to identical parts.

Referring first to Figs. 1, 2, 3, 4, the pulley 1 is adapted to transmit power from any prime mover through two combinations of bevel gears 2 and 3, compensating for the movements of the oscillating frame, to the bevel pinion 4 and gear teeth 5 carried on the crank disk 6. This disk is adapted to rotate in the movable carriage 7 slidable in the tracks 8—8.

The sides 9—9, containing tracks 8—8 and trunnions 10—10, together with the separator braces 11—11 form a rigid frame oscillating about the trunnions 10—10 between machined surfaces 12—12 on the main frame 13—13. The intermittent oscillating motion is imparted by worm 14 to segment 15 on arm 16, which is attached to sides 9—9.

By means of a reversing mechanism 68 to

71 it is possible to produce either a clockwise or an anti-clockwise movement of the oscillating frame or else have it set entirely at rest which action will be described below.

The center about which the crank disk 6 revolves is indicated at 18, see also Figs. 5 and 6. The tool 19 is carried upon the arm 20 slidably adapted to the disk 6 and its movement is controlled through the screw thread 21 actuated from the gear 22. Crank pin 23 is also slidably adapted to the crank disk 6 and its movement is controlled through the screw thread 24 actuated from the gear 25. Crank pin 23 is movable within slide 26, which slide is connected to and perpendicular at all times with tracks 8—8. The position of crank pin 23 relative to center 18 of disk 6 determines the movement of the carriage 7 in tracks 8—8 and the elliptical path 28 which the tool follows.

The gears 22 and 25 may be of any desired ratio, or combination of gears, as may also be the pitch of screw threads 21 and 24. The rotation of these screw threads is accomplished by the conventional star wheel and trip mechanism 27.

It will thus be seen that the operation of the pulley 1 causes the crank disk 6 to rotate in the carriage 7 about the center 18 which latter has a horizontal movement within the tracks 8—8, relative to the oscillating frame, and causes the crank pin 23 to move simultaneously in slide 26 perpendicular to that of center 18 so that through the resultant of both rectilinear motions and the rotating motion of the disk the tool 19 will generate the ellipse 28. The size of this ellipse may be varied progressively by the star wheel trip mechanism 27 operating feed screws 21 and 24. The rate of variation, to suit any predetermined requirements can be changed by varying the ratios of the gears 22 and 25 or the pitch of the screw threads 21 and 24 as before cited.

The trip mechanism 27 may be of any of a plurality of devices such as those well known in machine practice, and therefore not requiring any detailed description. It may employ the well known star wheel and pin or a ratchet and worm, or worm gear, in any case being suitably proportioned and timed, as a part of the driving means.

By actuating the gears 22 and 25 and employing any desired tooth ratios, the ellipses produced by the successive rotations of the disk 6 and the tool 19 may be decreased or increased as the case may be. In other words all such ellipses will have their major axes in the same vertical longitudinal central plane.

The preliminary roughing out by the tool of the desired internal or external surface I prefer to accomplish by the use of a milling cutter shown at 19. This cutter is preferably actuated by a train of suitably selected gears 29, (see also Fig. 5), independently driven by motor 30 mounted on bracket 31 and on carriage 7. The grinding and final polishing of the surface is accomplished by substituting abrasive wheels for the milling cutter.

These abrasive wheels are preferably actuated by a train of correctly proportioned sheaves 32 (see also Figs. 3, 4 and 6) driven from motor 30 through endless leather, rubber or fiber cords.

The before mentioned vertical movement is imparted to the table 33 carried in the vertical slides 34—34 by the roller 35 which rides upon a suitable cam surface, more specifically described below, thus causing the vertical raising or lowering of the table 33 and therefore of the block of raw material 36. It will be observed from Figs. 1 and 2 that the block 36 being in the form of a punch or an external surface, is lowered gradually against the tension of the spring members 37—37 and under the control of the roller and cams.

If it is desired to produce a die or an internal surface it is only necessary to place the roller 35 in the position 38 and reverse the spring members 37—37, and otherwise operate the machine as before. The table 33 will then be raised instead of lowered.

The single or master cam surface upon which the roller 35 rides is generated by laying off the ordinates of the parabolic or hyperbolic arc 39 respectively, (said arcs represent the locus of the center of all ellipses described by the tool 19), as successive radii from a base circle of 360° or less. Another way of producing a master cam is to base its generation on the loci of either the vertices 40—40 or the foci 41—41 of all ellipses described by the tool 19.

In order to secure a smooth quadric surface cut by the tool 19, I prefer to divide the master cam into a plurality of independent cam surfaces 42 to 48 inclusive (see Fig. 1) which are brought into action successively, each then contributing successively a portion of the movement to the table 33. A single or master cam may of course be substituted for the plurality of cams 42 to 48 here illustrated in which case table movement is actuated by a single cam surface, but in such cases the resulting work is not as accurate as where the movement is produced over a greater range of cam movement than that of one revolution of the master cam. I therefore prefer a plurality of consecutively operating cam members, 42 to 48, each moving successively through a large rotative range, thus securing in effect a greater degree of cam movement with respect to the table displacement. Thus, if the seven cams here shown be employed, each operating over a range of substantially 300° angular movement during the period of its contact with

and therefore raising of the roller 35, there will be substantially 2100° of angular movement and therefore a proportional travel of cam surface for the requisite table movement. I am thus able to get an effective cam surface of approximately 140″ on the seven cams while maintaining a relatively small diameter and I am able to secure the accuracy which would result from a cam about 6 ft. in diameter by utilizing a plurality of successively operating cams. During the movement of the cams the roller first rests upon the cam 48, all of the other cams being in their highest possible position. As cam 48 rotates through, say, its 300° of movement, the roller approaches closer and closer to the highest spot on cam 47, which is still stationary. When the radius on cam 48 under the roller exactly corresponds with the highest spot of cam 47, cam 48 rides clear of the roller and a depression in its surface permits the roller to now follow the slow receding of cam 47, whose movement likewise stops at the end of its stroke and when the roller just contacts with cam 46, cam 47 now likewise stops and the roller continues in its descending movement successively on the surfaces of cams 46, 45, 44, 43 and 42 until it rides in its lowest possible position, or if the movement of the table is desired to be automatically fed upward instead of downward, a reversal of the above action takes place, the roller starting its upward travel on the surface of cam 42, and being successively picked up and carried higher by the surface 43, 44, 45, 46, 47 and 48. It is to be understood that the roller 35 is carried on a spindle rigidly connected with the table 33.

The working range of each of the cams 43, 44, 45, 46 and 47 with respect to the master cam is preferably 30° circular measurement but expanded over an angle of 300° on each individual disc, in other words, these cams must travel at ten times as great an angular velocity as would the master cam. This plurality of independent cams are provided with grooves and pins whereby adjacent cams are permitted a movement of approximately 300° before the next cam is picked up by the pin of its adjacent cam working in its own slot, exactly in the same manner as the tumblers in a combination lock.

The cam 42 facilitating the initial abrupt vertical movement of the table covers a working range of only 8° circular measurement with respect to the master cam, but is expanded over 320° of movement of the shaft 49, in other words, this cam must travel at four times as great an angular velocity as the cams 43, 44, 45, 46, and 47 or 40 times as fast as the master cam. This result is accomplished by the application of two pairs of gears 50, 51, and 52, 53, each set having a ratio of 1 to 2. The gear 50 is keyed to the driving shaft 49 and the pinion 53 is attached to the cam 42 which rotates loosely on shaft 49. Meanwhile cam 43 which is keyed to the shaft 49 rotates also and comes into action at the end of the effective movement of cam 42. After an angular movement of 300° about the axis of 49, cam 43 with its pin, which has been travelling in a groove in the adjacent cam 44, picks up this cam and brings it into action. These grooves and pins are similar to pins 86 and grooves 101 in Figs. 7, 8 and 9, except that they are in the form of arcs instead of straight slots. After an angular movement of 300° of cam 44 its pin in turn picks up the next cam 45 and brings it into action. Thereafter cams 46, 47 and 48 are successively picked up by the pins of the cam immediately before and they each are given the desired successive movement. Thus the roller 35 riding on the surface of the successive cams transfer the appropriate vertical movement to the block of raw material 36. The manner in which the cams are successively brought into action is best shown in Fig. 8, wherein the plurality of cams 72 to 79 inclusive are provided with a plurality of pins 86 projecting from the flat surface of the cam and engaging the adjacent cam in a slot or recess of a length corresponding with the desired freedom of movement between the cams (see Figs. 7, 8 and 9). It will be readily understood that a similar construction wherein the slots are arcs about the axis 49 of the cam movement may be employed between the cams 42 to 48 of Figs. 1 and 2, the pin of one cam riding in the adjacent arcuate slot in the adjacent cam, the said slot being of sufficient length to allow the desired freedom of movement.

All of these cam movements are successive and intermittent and produced by the agency of ratchet 54 and pawl 55 which latter is operated by cam 56. This cam is driven at a constant rate of speed through a set of gears 57 and 58 from the main driving shaft 59 and the driving pulley 1.

Thus far, only the vertical motions corresponding to the ordinates of the parabolic or hyperbolic arc have been considered. The horizontal motions corresponding to their abscissæ must be provided to obtain the ultimately desired curvatures of the surfaces specified.

This is accomplished by an intermittent lateral movement of crank pin 23 with respect to the table 33, as illustrated in Fig. 1. This movement originates with shaft 49 which actuates through bevel gears 60 and 61, the vertical shaft 62. Bevel gear 63 drives horizontal shaft 64 which carries a set of bevel gears at the end near the main frame 13—13. The vertical shafts 65 through a group of bevel gears 66, finally

operate the feed screws 67—67 which impart the lateral movement to slide 26 and finally to crank pin 23. The vertical shafts 65 are able to compensate for any variations in length and position due to the operation of the oscillating frame by a conventional sliding and swinging motion around the horizontal shaft 64 and the group of bevel gears 66 as centers.

In the production of an external surface of a punch, as illustrated in Fig. 1, whose horizontal diverging sections are ellipses of varying sizes and whose vertical axial sections are hyperbolic arcs of variable parameter, it is necessary to intermittently rotate the oscillating frame in an anti-clockwise direction so that the planes of the ellipses described by the milling cutter or grinding wheel coincide with the planes through the focal radii drawn through the virtual focus of the hyperbolic arc 40. In the production of an internal surface of a die of the same description it is necessary to rotate the oscillating frame in a clockwise direction. In the production of a punch or a die, whose horizontal, parallel sections are ellipses of varying sizes and whose vertical axial sections are parabolic arcs of variable parameter it is necessary to lock the oscillating frame in a horizontal position.

These various operations of the oscillating frame are controlled through a reversing mechanism consisting of bevel gear 68 mounted on a sleeve jointly with worm 14, bevel gear 69, mounted loosely on shaft 62, bevel gear 70 turning freely on a stud and a jaw clutch member 71 slidably keyed to shaft 62. The sleeve with gear 68 and worm 14 also turns freely on shaft 62. When member 71 is locked with gear 68 the worm 14 will attain the same rotary motion as shaft 62, whereas by locking member 71 with gear 69, the worm will attain the opposite rotary motion as shaft 62 and by placing member 71 in a neutral position, the worm 14 and with it the oscillating frame, will remain at rest.

In Figs. 3 and 4 is shown a modification for effecting the horizontal motion which corresponds to the abscissæ of the parabolic or hyperbolic arc and which motion is based on the loci of the vertices 40—40, or of the foci 41—41 or on the locus of the centers 39, of all the ellipses described by the tool. Instead of moving the crank pin 23 laterally, as shown in Fig. 1, I impart a horizontal motion to the table 33. The horizontal movement of the carriage corresponding with the abscissæ of the second degree curve which it is desired to generate are produced through the rotation of the shaft 59 as a prime mover through conventional gears which actuate the feed screw 100. (See Figs. 3 and 4). A further modification shown in Figs. 3, 4, 7, 8, and 9 is the substitution of a nest of sliding cams for the nest of revolving cams, previously described, wherein I accomplish the doubling of the working range of the cam, i. e., a greater accuracy or, accepting the same accuracy of the revolving cams, a fewer number of sliding cams. Another advantage lies in the fact that each sliding cam is propelled individually by the driving shaft instead of through a series of pins.

Referring particularly to Fig. 7, the group of sliding cams 72 to 80 inclusive is shown ready to begin the work of milling, grinding or polishing the internal surface of a die. All of the cams slide on a grill of parallel guide bars 85—85. Cams 73 to 80 are provided with racks on their undersides which mesh, during the period of the effective movement of each cam, with pinions 83—83 on driving shaft 81. Cam 72 is designed to facilitate the abrupt vertical movement of the table at the beginning of the operation and has four times the linear speed of the other sliding cams being propelled independently by gear 82 simultaneously with the cam 73 which latter comes into action only at the end of the effective movement of cam 72. By means of conical pins 86 sliding in dove-tail grooves each cam is successively brought into action and propelled by its corresponding pinion as 83 through its successive range of movement. Stationary blocks 84 riding on the shaft 81 afford an effective support for the guide bars 85 under the weight imposed by the rollers 35.

Fig. 9 illustrates the arrangement of the sliding cams for the milling, grinding or polishing of the external surface of a punch. The position of the cams and driving shaft is the reversal of the one shown in Fig. 7. The worm gear 87 is keyed to shaft 81 and engaged by a worm 88 on shaft 89, see Fig. 4. This shaft and worm are not affected by the reversal of the cams in changing over from cutting the die to cut the punch.

If desired, driving connections, gear ratios, etc., may be altered from time to time to suit the requirements of any individual surface to be produced. But it is to be borne in mind that while the table 33 is undergoing its respective movements that the elliptic chuck is simultaneously causing the tool to describe a series of horizontal parallel or horizontal diverging ellipses of varying sizes, so that the surface of the solid cut by the tool 19 will be one whose longitudinal vertical central section will be either a parabolic or a hyperbolic arc and whose horizontal parallel or horizontal diverging sections will be ellipses of varying sizes; that is a conicoidal or quadric surface as above set forth.

Reference is herein made to my co-pending application No. 716,833, filed May 29th, 1924, wherein is set forth further disclosure and

descriptive matter bearing upon this invention.

I claim:

1. Apparatus for generating quadric surfaces comprising a stationary frame, a cutting tool and independent motor means for operating said tool, a chuck and driving connections therefor compelling the movement of said tool, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool, means constructed and adapted to move said tool and other means constructed and adapted to move said material relative to said tool whereby the material is cut in a plurality of complete horizontal ellipses whose major and minor axes are progressively changed on second degree curves.

2. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with respect to said frame and said tool.

3. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with a vertical component, and other actuating connections for simultaneously moving said carriage with a horizontal component.

4. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with a vertical component, and other actuating connections for simultaneously moving said carriage with a horizontal component, said components corresponding with the ordinates and abscissæ of a second degree curve.

5. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a plurality of automatically selected complete elliptic paths of different dimensions, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path.

6. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool, and cam devices adapted to move said carriage with respect to said frame and said tool.

7. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool, and cam devices adapted to move said carriage with a vertical component and other actuating connections for simultaneously moving said carriage with a horizontal component.

8. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary to amplitude of the said elliptic path, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool, and cam devices adapted to move said carriage with a vertical component and other actuating connections for simultaneously moving said carriage with a horizontal component, said components being in accord with the ordinates and abscissæ of a second degree curve.

9. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a plurality of automatically selected complete elliptic paths of different dimensions, mechanism adapted to periodically and successively vary the amplitude of the said elliptic paths and other mechanism automatically varying the plane of the successive elliptic paths.

10. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic

path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path, and other mechanism automatically varying the plane of the successive elliptic paths, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with respect to said frame and said tool.

11. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path, and other mechanism automatically varying the plane of the successive elliptic paths, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with respect to said frame and said tool with a vertical component and other actuating connections for simultaneously moving said carriage with a horizontal component.

12. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path, and other mechanism automatically varying the plane of the successive elliptic paths, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with respect to said frame and said tool with a vertical component and other actuating connections for simultaneously moving said carriage with a horizontal component, said components corresponding with the ordinates and abscissæ of a second degree curve.

13. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a plurality of automatically selected complete elliptic paths of different dimensions, mechanism adapted to periodically and successively vary the amplitude of the said elliptic paths and other mechanism automatically varying the plane of the successive elliptic paths and comprising tracks carrying said chuck, said tool and tool rotating parts being on a pivoted axis carried on said frame and in the plane of the tool's rotation.

14. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path and other mechanism automatically varying the plane of the successive elliptic paths and comprising tracks carrying said chuck, said tool and tool rotating parts being on a pivoted axis carried on said frame and in the plane of the tool's rotation, a carriage mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with respect to said frame and said tool.

15. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path and other mechanism automatically varying the plane of the successive elliptic paths and comprising tracks carrying said chuck, said tool and tool rotating parts being on a pivoted axis carried on said frame and in the plane of the tool's rotation, a carriage mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with respect to said frame and said tool with a vertical component and other actuating connections for simultaneously moving said carriage with a horizontal component.

16. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path and other mechanism automatically varying the plane of the successive elliptic paths and comprising tracks carrying said chuck, said tool and tool rotating parts being on a pivoted axis carried on said frame and in the plane of the tool's rotation, a carriage mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with respect to said frame and said tool with a vertical component and other actuating connections for simultaneously moving said carriage with a horizontal component, said components corresponding with the ordinates and abscissæ of a second degree curve.

17. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with respect to said frame and said tool comprising a plurality of successively engaged cams each contributing a vertical component of movement to said carriage.

18. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with respect to said frame and said tool comprising a plurality of successively engaged cams each contributing a vertical component of movement to said carriage and other devices and connections simultaneously moving said carriage with a horizontal component.

19. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool and cam devices adapted to move said carriage with respect to said frame and said tool comprising a plurality of successively engaged cams each contributing a vertical component of movement to said carriage and other devices and connections simultaneously moving said carriage with a horizontal component, said component being in accord with the ordinates and abscissæ of a second degree curve.

20. Apparatus as set forth in claim 4 and driving means carried on said frame and adapted to drive said driving connections, actuating connections and said cam devices and said carriage.

21. Apparatus as set forth in claim 8 and driving means carried on said frame and adapted to drive said driving connections, actuating connections and said cam devices and said carriage.

22. Apparatus as set forth in claim 16 and driving means carried on said frame and adapted to drive said driving connections, said carriage, said actuating connections, said cam devices, said mechanism and said other mechanism.

23. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool, and timed means shifting said chuck in accord with the abscissæ of a second degree curve.

24. Apparatus as set forth in claim 23 and cam devices adapted to move said carriage with respect to said frame and said tool in accord with the ordinates of a second degree curve.

25. Apparatus as set forth in claim 23 and cam devices adapted to move said carriage with respect to said frame and said tool and other mechanism automatically varying the plane of the successive elliptic paths.

26. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path, and other mechanism automatically varying the plane of the successive elliptic paths, a carriage slidably mounted in said frame and adapted to support raw material positioned before said tool, and cam and screw devices adapted to move said carriage with respect to said frame and said tool and other mechanism automatically varying the plane of the successive elliptic paths.

27. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path and other mechanism automatically varying the plane of the successive elliptic paths and comprising tracks carrying said chuck, said tool and tool rotating parts being on a pivoted axis carried on said frame and in the plane of the tool's rotation.

28. Apparatus for generating quadric surfaces comprising a stationary frame, a rotary cutting tool and independent motor means for rotating said tool, a chuck and driving connections therefor compelling the movement of said tool in a selected elliptic path, mechanism adapted to periodically and successively vary the amplitude of the said elliptic path and other mechanism automatically varying the plane of the successive el-

liptic paths and comprising tracks carrying said chuck, said tool and tool rotating parts being on a pivoted axis carried on said frame and in the plane of the tool's rotation, a carriage mounted in said frame and adapted to support raw material positioned before said tool and cam and screw devices adapted to move said carriage with respect to said frame and said tool.

29. In apparatus for generating an internal quadric surface, a tool and mechanism constructed and adapted to move said tool in a single plane and in adjustable elliptical paths, a table adapted to receive raw material on which the tool is adapted to work, and means causing the table movement in a parabolic path at right angles to the plane of said ellipses.

30. In apparatus for generating an internal quadric surface, a tool and mechanism constructed and adapted to move said tool in a single plane and in adjustable elliptical paths, a table adapted to receive raw material on which the tool is adapted to work, and means causing the table movement in a parabolic path at right angles to the plane of said ellipses and operating devices to drive the tool controlling mechanism and the means causing the table movement in timed relation.

31. A machine for producing internal quadric surfaces comprising a cutting tool and mechanism constructed and adapted to move said tool to generate concentric ellipses, a template, a table movable against said template and having mechanism causing another movement at right angles with respect to said template movement, whereby the combination of said movements is a parabolic path with respect to any fixed point in the said machine.

32. A machine for producing internal quadric surfaces comprising an adjustable cutting device constructed and adapted to produce horizontal internal cuts in elliptical paths of varying size and a table adapted to carry raw material and means giving said table an upward motion and a horizontal motion on a parabolic path in timed relation to the adjustment of the cutting device which path is the locus of the foci of the varying ellipses generated by the tool.

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