April 26, 1960 H. G. MURPHY 2,933,965

METHOD AND APPARATUS PROVIDING AN INFINITE RANGE OF RADII FOR GENERATING SPHERICAL SEGMENTS AND CURVED SURFACES

Filed Oct. 8, 1957 4 Sheets-Sheet 1

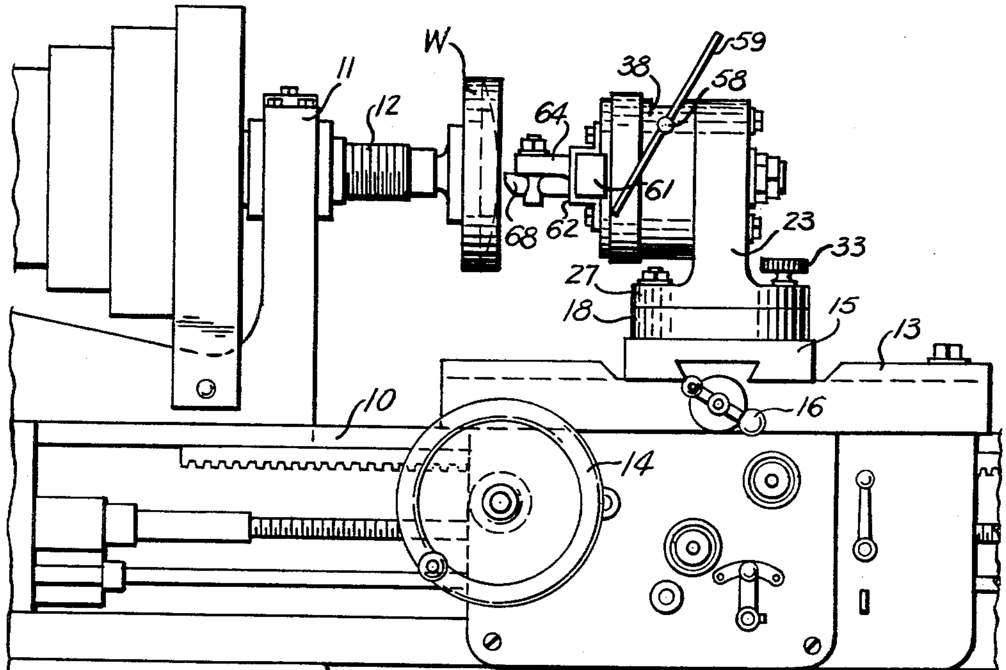

FIG. 1

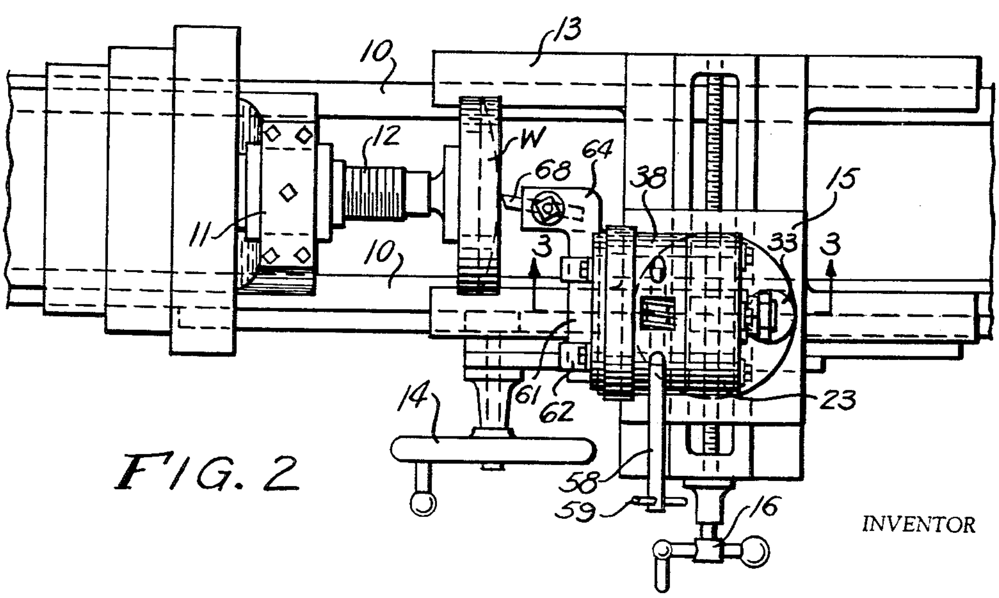

FIG. 2

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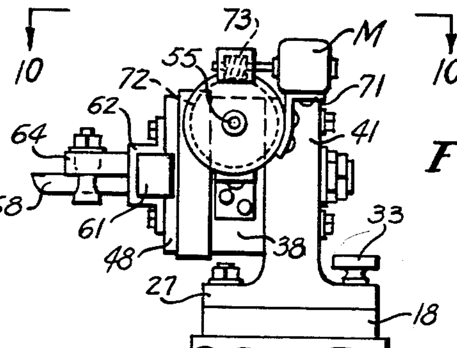

FIG. 9

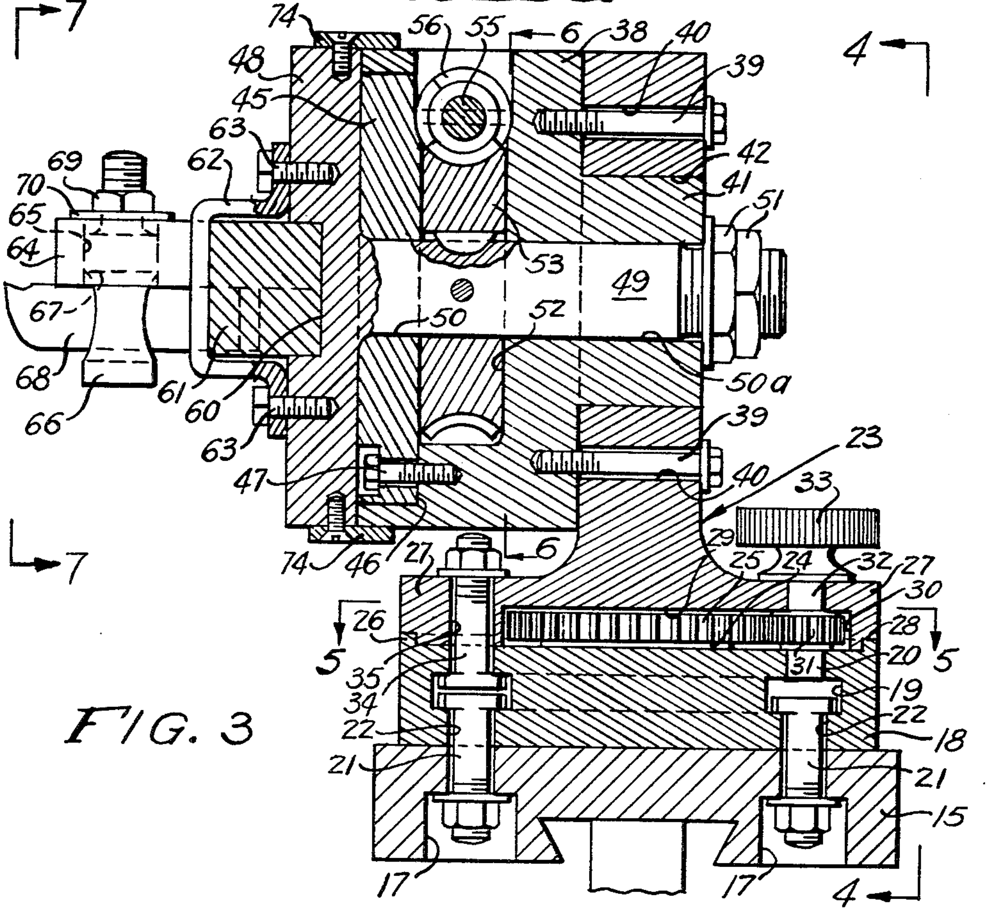

FIG. 3

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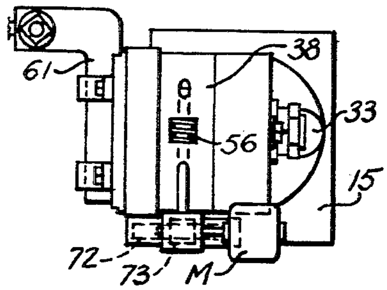

FIG. 10

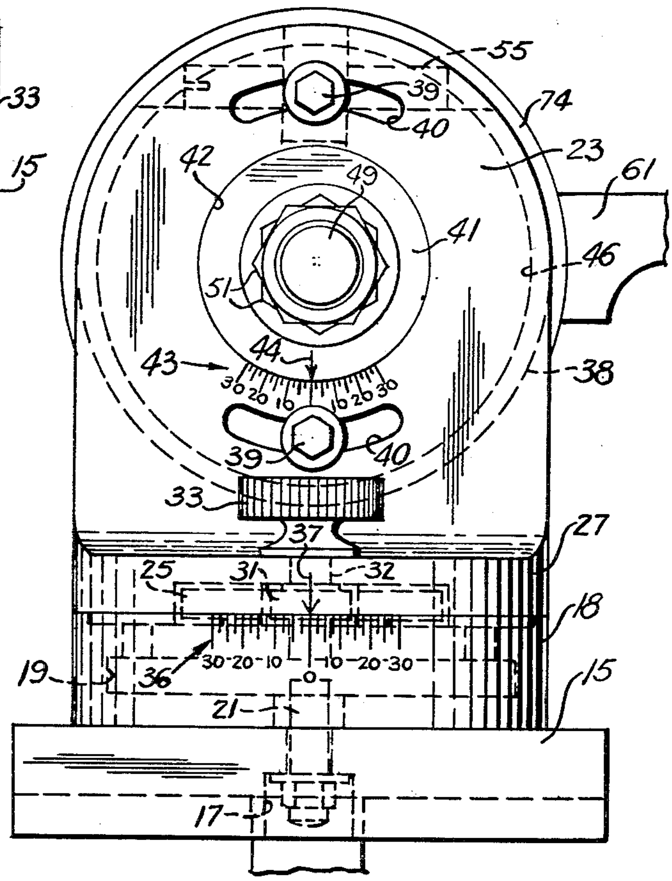

FIG. 4

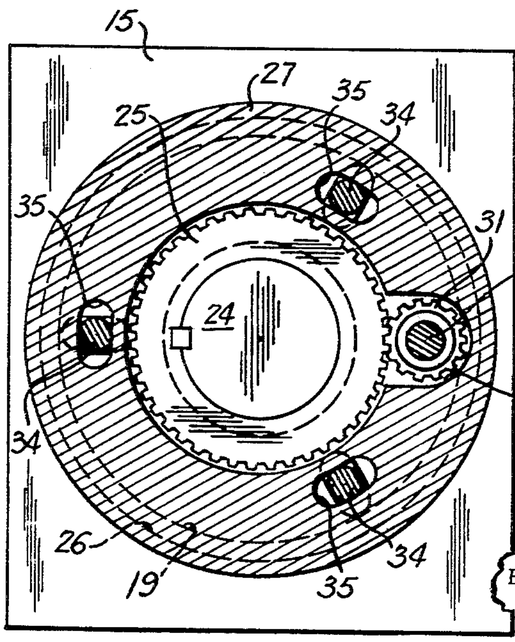

FIG. 5

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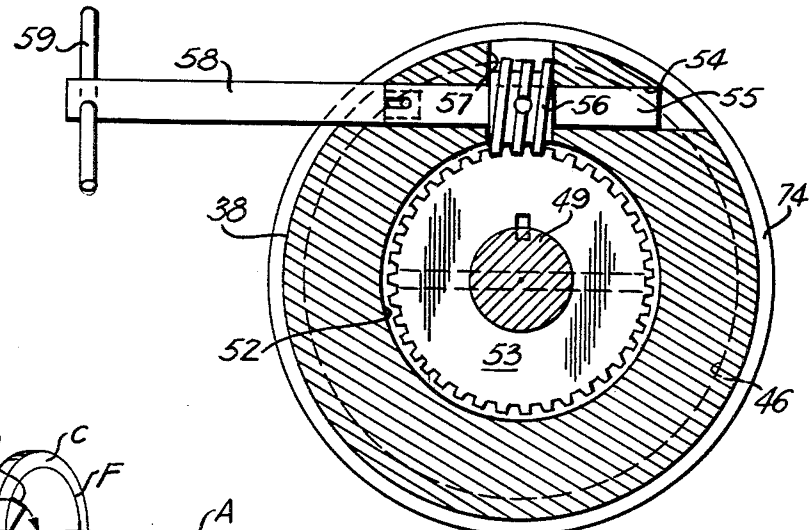

FIG. 6

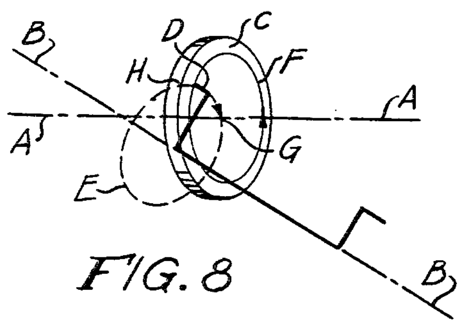

FIG. 8

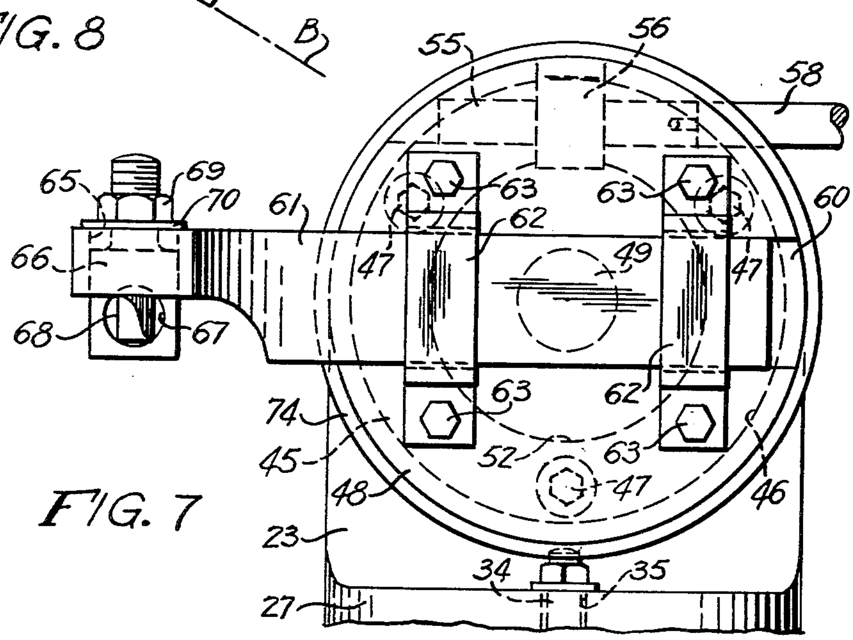

FIG. 7

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United States Patent Office

2,933,965

Patented Apr. 26, 1960

2,933,965

METHOD AND APPARATUS PROVIDING AN INFINITE RANGE OF RADII FOR GENERATING SPHERICAL SEGMENTS AND CURVED SURFACES

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Application October 8, 1957, Serial No. 688,997

5 Claims. (Cl. 82—12)

This invention relates to a method and apparatus which provides an infinite range of radii for generating spherical segments and curved surfaces on a workpiece.

In the metal working art, one of the major technical problems has been that of generating or forming a true segmental spherical surface having a long radius of curvature. An example of such a surface is what is commonly called in the lens grinding trade a metal lap, and these are most commonly used in the optical arts for the production of opthalmic and precision lenses or the like. In the lapping process the glass body is ground to a shape conforming to that of the lap by moving it continuously in random directions across and against the lap as a grinding compound is applied. Therefore, there exists the problem not only of making the original lap at a reasonable cost, but in truing up the laps after they have worn beyond the point of minimum accuracy by the grinding compound. The need for truing the laps occurs in many small shops which do not have the resources to afford the expensive and complex machinery heretofore used in forming or truing the laps nor do they have the space for housing the cumbersome, large-spread machinery.

In previously known methods and apparatus for forming or truing a lap, one of the most commonly used has been a radius bar fixture, wherein the radius of the bar has been equal to the radius of curvature of the desired spherical surface. In the curves of longer radii this has involved a very large and heavy device. The leverage through which the force applied at the point of the tool acts is so great that there is chattering of the tool on the work and only light cuts may be taken. In the way of example, a one-eighth diopter lens lap requires a radius bar of fourteen feet. Another method of cutting the laps has been by the use of electrically, hydraulically or pneumatically controlled tracer machinery, and this apparatus is complex, very costly and can only be handled by experts who have been especially trained for that purpose. This usually presents the problem of making the master pattern. Still another way of cutting the lap has been by use of the ball turning attachment. These attachments are very limited in range, because the diameter of the work is limited by the radius of the arm carrying the tool bit.

It may be pointed out that this problem is not restricted to the lens grinding field. The need for generation of a true spherical surface occurs in the tool and die industry and in the pattern making arts.

There has been a strong need, therefore, for a method and apparatus which is more simplified and less costly than that presently known, which is in a cost and size range that can be handled by the smaller shops, and which is within the capability of the average craftsman.

It is an object of this invention to provide apparatus which in its preferred form is in the nature of an attachment to a standard metal cutting lathe, but which may

also be applied to other metal working machine tools which have a rotatable spindle for holding a workpiece, such as milling machines and boring mills.

It is a further object of the device to provide an inexpensive and simple method and apparatus capable of use in a small shop for generating a spherical segment of any selected plus or minus radius ranging from slightly above zero to infinity, and which method and apparatus does not require any unusual degree of skill, and is within the capability of the average trained machinist.

Still another object of the invention is to provide a method and apparatus wherein the surface generated may be a positive spherical segment, a plano surface or a negative spherical segment.

Still another object of the invention is to provide apparatus of simple and inexpensive construction which has a range in one machine that is equivalent to that which formerly had to be provided by several different machines, and which can accomplish the work of the radius bar, ball turning attachments and tracing devices which are now in common use for generating spherical segments and curved surfaces.

Still another object of the invention is to provide a method and apparatus capable of generating accurate spherical segments without tool chatter marks and of such quality that handwork is not required for the finished surface.

A further object of the invention is to provide a method and apparatus which is not limited solely to cutting spherical segments but which may also be used to cut internal and external radii, such as bearing races and the like.

A further object of the invention is to provide an apparatus which is capable of rapid and ready adjustment for turning a surface of any selected radius.

Another object is to provide apparatus which is of rigid construction which is capable of operation in a confined area and which operates close to the headstock of the lathe machine tool, the cutting tool overhang being at a minimum, thus minimizing the nuisance of tool chatter.

Still another object of the invention is to provide a method and apparatus which with minor changes can be adapted to grinding or metal spinning operations. For example, a grinding quill can be used instead of a tool bit, laps and dies can be ground to a mirror finish, glass lens blanks can be rough ground with a diamond abrasive wheel, and flat metal sheets can be spun into segmento-spherical shells.

With the above and other objects in view, as will be presently apparent, the invention consists in general of certain novel details of construction and combinations of parts hereinafter fully described, illustrated in the accompanying drawings and particularly claimed.

In the accompanying drawings like characters of reference indicate like parts in the several views, and:

Fig. 1 is a fragmentary front elevational view of a metal working lathe with the attachment of the invention in place on the lathe bed and in position to be adjusted for a cut of selected radius of curvature, the surface to be generated being shown by dotted lines;

Fig. 2 is a fragmentary top plan view of the attachment as applied to a metal working lathe;

Fig. 3 is a cross-sectional view of the attachment taken on the line 3—3 of Fig. 2;

Fig. 4 is a fragmentary view of the attachment taken in the direction of the arrow 4 in Fig. 3;

Fig. 5 is a cross-sectional view taken on the line 5—5 of Fig. 3;

Fig. 6 is a cross-sectional view taken on the line 6—6 of Fig. 3;

Fig. 7 is a fragmentary elevational view taken in the direction of the arrows 7 in Fig. 3;

Fig. 8 is a schematic view illustrating the method involved in the present application and showing the path of the tool relative to the plane of rotation of the workpiece during a cutting operation;

Fig. 9 is a modification of the attachment of the present invention wherein an electric motor is applied for causing movement of the tool bit in its desired path over the work; and

Fig. 10 is a further view of the same modification taken in the direction of the arrows 10 in Fig. 9.

The present invention involves both a novel method and a novel and preferred apparatus for carrying out the method. Since different forms of apparatus might be developed and used in applying the method, the method will first be described in detail and the preferred form of apparatus will then be separately and more fully disclosed.

The method can best be disclosed by reference to the schematic diagram shown in Fig. 8 of the drawings. The line A—A represents the axis of rotation of a workpiece C. It is essential that the plane of this workpiece C be normal to the axis A—A and that the axis be fixed. A cutting tool D is then made to revolve about an axis B—B, and if this tool were revolved in a full circular path of 360°, this path would be represented by the broken line E. In carrying out the method, it is necessary that the plane of the path E be made to intersect the plane of rotation of the workpiece, that the peripheral path E of the cutting tool move through the axis of rotation of the workpiece, and that the axis of rotation of the tool intersect the axis of rotation of the workpiece.

If these relationships are established and held, if the workpiece C is rotated and the cutting tool is slowly moved about its axis B—B in an arcuate path from the point G to the point H, or alternately from H to G, a spherical surface will be generated on the face of the workpiece.

By placing the axis of rotation B—B so that it intersects the axis of rotation A—A of the workpiece behind the workpiece, as shown in Fig. 8, a positive or convex surface may be generated. On the other hand, if the axis of rotation B—B of the tool is made to intersect the axis of rotation in front of the workpiece, a negative or concave surface will be generated.

The present application discloses a preferred and novel apparatus for carrying out the method involved and this apparatus is designed to be attached to a standard metal working lathe or other suitable machine tool. The reference numeral 10 indicates the ways of a standard and known lathe. The lathe is provided with a headstock 11 and any known chuck 12 for holding a workpiece W. This workpiece is usually preworked to provide it with a chuck-holding spindle, which later is used to hold the lap in the lapping machine. A feed carriage 13 slides along the ways 10 and is controlled and moved by the hand-crank 14. A crossfeed carriage moves on ways on the feed carriage 13 and is controlled by the hand-crank 16. The crossfeed carriage 15 is provided with bolt holes 17, as shown in Fig. 3. Up to this point all the construction described is standard and well known in the art.

The attachment of the present invention is provided with a base plate 18, which has formed therein an annular T-slot 19 with the narrow neck of the slot opening upwardly. This base plate 18 is fixed to the crossfeed carriage 15 by T-bolts 21 which are inserted through apertures 22 in the base plate below the T-slots. The base plate is further provided with an upwardly directed, integrally formed boss 24 which supports a ring-shaped element that is formed into a ring gear 25 by the cutting of gear teeth in the peripheral edge thereof. This ring gear 25 is keyed to the boss 24 or is integrally formed therewith, as desired.

A frame bracket 23 is rotatably mounted on the base plate 18, and the base plate is preferably provided with an upstanding annular flange 26 which cooperates with a corner groove 28 in the circular base 27, so that the base plate 18 and circular base 27 will remain in accurate alignment during relative rotation. The circular base 27 is provided with a large bore 29 for receiving the ring gear 25 and a smaller intersecting counterbore 30 for receiving a pinion 31 which meshes with the ring gear 25. The pinion 31 is mounted on a stub shaft 32 which extends through the upper wall of the circular base, and a knurled knob 33 is fixed to the stub shaft. At least three bolts 34 extend through apertures 35 in the circular base and the heads of these bolts engage the annular T-slots 19 in the base plate 18. The base plate 18 is preferably provided with a scale 36 and the circular base 27 with an arrow or indicating mark 37. When the attachment is in use this provides an indication of the angle of inclination of the tool bit axis to the axis of rotation of the work, which angle controls the radius of curvature of the spherical segment generated.

A gear housing 38 is mounted upon and secured to the frame bracket 23 by means of the screws 39. Each of the screws projects through a segmental arcuate slot 40 formed in the frame bracket 23. The gear housing 38 has formed thereon an eccentric boss 41 which is rotatable in a circular opening 42 formed in the frame bracket 23. An indicating scale 43 is placed on the eccentric boss 41, with the "0" of the scale being positioned at the point of smallest radius of the eccentric boss. Rotation of the gear housing about its eccentric boss 41 will raise or lower the shaft 49, as will later be described, and tightening of the screws 39 will then hold the gear housing 38 in adjusted position.

The gear housing 38 is provided with a cover 45 which is countersunk in a groove 46 in the outer edge of the housing, the cover being fastened by screws 47. A tool bar platen 48 is mounted on the gear housing 38 and this platen is provided with a shaft 49 which is journalled for rotation in apertures 50 and 50^a in the cover 45 and eccentric boss 41, respectively. The inner end of the shaft 49 is threaded and is provided with locknuts 51. These locknuts permit the shaft to be set tightly enough to prevent play, but with just enough clearance for rotation.

The gear housing 38 is further provided with a bore 52 which receives a worm wheel 53 which is keyed to the shaft 49. The said housing is provided with a transverse bore 54 in which is journalled the shaft 55, and an intersecting vertical opening 57 which houses a worm 56 which is pinned or keyed to the shaft 55. The shaft 55 is provided with an extension 58 and a finger bar 59 by means of which the shaft may be manually rotated. Rotation of the shaft 55 will cause rotation of the worm 56, the worm gear 53, and the platen 48 about the axis of its shaft 49.

The platen 48 is provided with a transverse groove 60 which receives a heavy tool bar 61. This tool bar is held in adjusted position in its groove 60 by means of the straps 62 which are fixed to the platen 48 by means of the screws 63. The tool bar is provided with a hooked end 64, which has a transverse bore 65 formed therein. A pin 66 slides within the bore 65 and the head of the pin is provided with a through opening 67, which is slightly larger in diameter than the thickness of a tool bit 68 which is positioned therein. The upper end of the pin 66 is threaded and provided with a nut 69 and washer 70. Tightening of the nut 69 will cause the tool bit 68 to be drawn tightly against the under surface of the hooked end 64 of the tool bar 61, and it will be firmly held in adjusted position.

In the modifications shown in Figs. 9 and 10, it is shown that it is possible to drive the shaft **55** and worm **56** by means of a motor M which is mounted on the gear housing **38** by means of a bracket **71**. Since the shaft **55** must revolve slowly, the shaft **55** is provided with a large gear **72** and the motor M is provided with a small gear **73**. Suitable power lines and switch means, not shown, will be provided for the motor.

If the attachment is used on a variable speed lathe, the power for rotating the shaft **55** could be supplied by a universal joint take-off from the lathe cross-slide power feed. This would provide maximum accuracy and surface finish.

In order to provide a seal between the platen **48** and the gear housing **38**, a wiper ring or sleeve **74** may be provided to cover the joint, as best shown in Fig. 3.

The operation of the apparatus described is as follows: The workpiece W is mounted in the chuck or spindle **12** and securely tightened. The bolts **34** of the frame bracket **23** are then loosened, and the frame bracket **23** is rotated to the desired setting on the scale **36** by turning the knob **33**. As the pinion **31** is turned by the knob, the fact that it meshes with the gear ring **25** causes the frame bracket to be rotated. The effect of the rotation of the frame bracket **23** is to vary the angle of inclination of the axis of rotation of the tool, namely the shaft **49**, to the axis of rotation of the workpiece W. It is this angle of inclination which determines the radius of curvature of the spherical segment generated. With reference to the schematic showing of Fig. 8, if the angle of inclination of the axis B—B to the axis A—A is very small, the radius of curvature will be very large. As the angle of inclination is moved closer to 90°, the radius of curvature of the generated surface will become progressively smaller. Therefore, when the desired angle of the axis of rotation of the tool has been attained, the bolts **34** are tightened securely.

It is important that the axis of rotation of the shaft **49** intersect the axis of rotation of the workpiece W, which is the centerline of the lathe. This is accomplished by loosening the screws **39** and rotating the gear housing **38** about its eccentric boss **41**. This will raise or lower the shaft **49** by a measured amount and until the desired intersection of axis is obtained. The screws **39** are then tightened to fix the housing **38** and shaft **49** in adjusted position.

These adjustments having been made, the crossfeed carriage **15** is then moved by the hand-crank **16** until the tool bit point as it rotates about the shaft **49** moves through the axial center of the workpiece.

The final adjustment having been completed, the lathe is ready for the cutting operation. The cut is normally taken from the outside diameter toward the center of the workpiece. The tool bit it brought into contact with the work by moving the feed carriage **13** with the hand-crank **14**. The shaft **55** is then rotated counterclockwise until the tool bit **68** is outside of the maximum diameter of the workpiece. The depth of the cut is controlled by the amount the feed carriage **13** is moved toward the work, and when this has been set, the shaft **55** is turned clockwise by the finger bar **59** to move the tool bit **68** against the work. The tool bit first comes into contact with the outside diameter of the work and this rotation of the shaft **55** is continued until the tool bit passes through the dead center thereof. Additional cuts are made by moving the feed carriage **13** an increment toward the work, and the swing of the tool bit by the shaft **55** is repeated. If necessary, and if the work is inaccurate upon testing, adjustments may be made in the basic settings. The cuts are then repeated until work cleans up and a suitable surface finish is achieved.

It will thus be seen that the method and apparatus disclosed provides in one operation and one piece of apparatus a range of radius of curvature which is substantially infinite. The surface generated may range from the smallest radius that is practical relative to the size of the tool parts to a radius that is infinite, since if the adjustments are such that the axis of rotation of the tool bit is parallel to the axis of rotation of the workpiece, a plano surface will be cut.

While there are herein shown and described the preferred embodiments of the method and apparatus, it is to be understood that minor changes may be made therein without departure from the spirit and scope of the invention as claimed. It will be evident that if adjustments in the settings were made, a curved surface other than a spherical segment could be generated on the work.

What is claimed is:

1. A machine tool comprising a work holding spindle, a set of ways, said spindle being parallel to said ways, a tool feed carriage on said ways, a crossfeed carriage on said feed carriage disposed in a plane parallel to said ways, a base, means for fixedly attaching said base to said crossfeed carriage, a frame bracket rotatably mounted on said base about an axis perpendicular to a plane parallel to said ways, means for fixing said frame bracket in adjusted rotated position about said axis, a shaft journalled for rotation in said frame bracket and positioned substantially parallel to said ways, means to rotate said shaft, a tool holding means secured to the outer end of said shaft and extending transversely thereof, and a cutting tool secured to one end of said tool holding means.

2. A machine tool comprising a work holding spindle, a set of ways, said spindle being parallel to said ways, a tool feed carriage on said ways, a crossfeed carriage on said feed carriage disposed in a plane parallel to said ways, a base, means for fixedly attaching said base to said crossfeed carriage, a frame bracket rotatably mounted on said base about an axis perpendicular to a plane parallel to said ways, means for fixing said frame bracket in adjusted rotated position about said axis, a bearing housing secured to said frame bracket, a shaft journaled for rotation in said bearing housing and positioned substantially parallel to said ways, means to raise and lower said bearing housing and to fix said housing in a selected adjusted position, means to rotate said shaft, a tool holding means secured to the outer end of said shaft and extending transversely thereof, and a cutting tool secured to one end of said tool holding means.

3. A structure as set forth in claim 1, wherein the means to raise and lower said bearing housing includes an eccentric boss extending from said housing into a circular opening in said frame bracket, and said means to fix said housing in a selected adjusted position includes a plurality of bolts secured to said housing, each of said bolts extending through an arcuate slot in said frame bracket.

4. A machine tool comprising a work holding spindle, a set of ways, said spindle being parallel to said ways, a tool feed carriage on said ways, a crossfeed carriage on said feed carriage disposed in a plane parallel to said ways, a base, means for fixedly attaching said base to said crossfeed carriage, a frame bracket rotatably mounted on said base about an axis perpendicular to a plane parallel to said ways, means for fixing said frame bracket in adjusted rotated position about said axis, a shaft journaled for rotation in said frame bracket and positioned substantially parallel to said ways, means to rotate said shaft, a platen at the outer end of said shaft, a tool bar positioned against said platen and extending transversely thereof, means to clamp said tool bar to said platen, and a cutting tool secured to one end of said tool bar.

5. The method of generating a segmental true spherical surface on a workpiece with a cutting tool, wherein the radius of curvature of said surface may be selected from a range starting from above zero and ending below infinity, comprising the steps of rotating said workpiece about a fixed axis in a plane normal to said axis and moving a cutting tool against the workpiece about an

axis of rotation and through a sector of a fixed circular path, while holding the workpiece and cutting tool so related that the axis of rotation of said tool intersects the fixed axis of said workpiece, that the plane of said sector intersects at an acute angle the plane of rotation of said workpiece, and that the circular path of said tool moves through the said fixed axis of the workpiece.

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