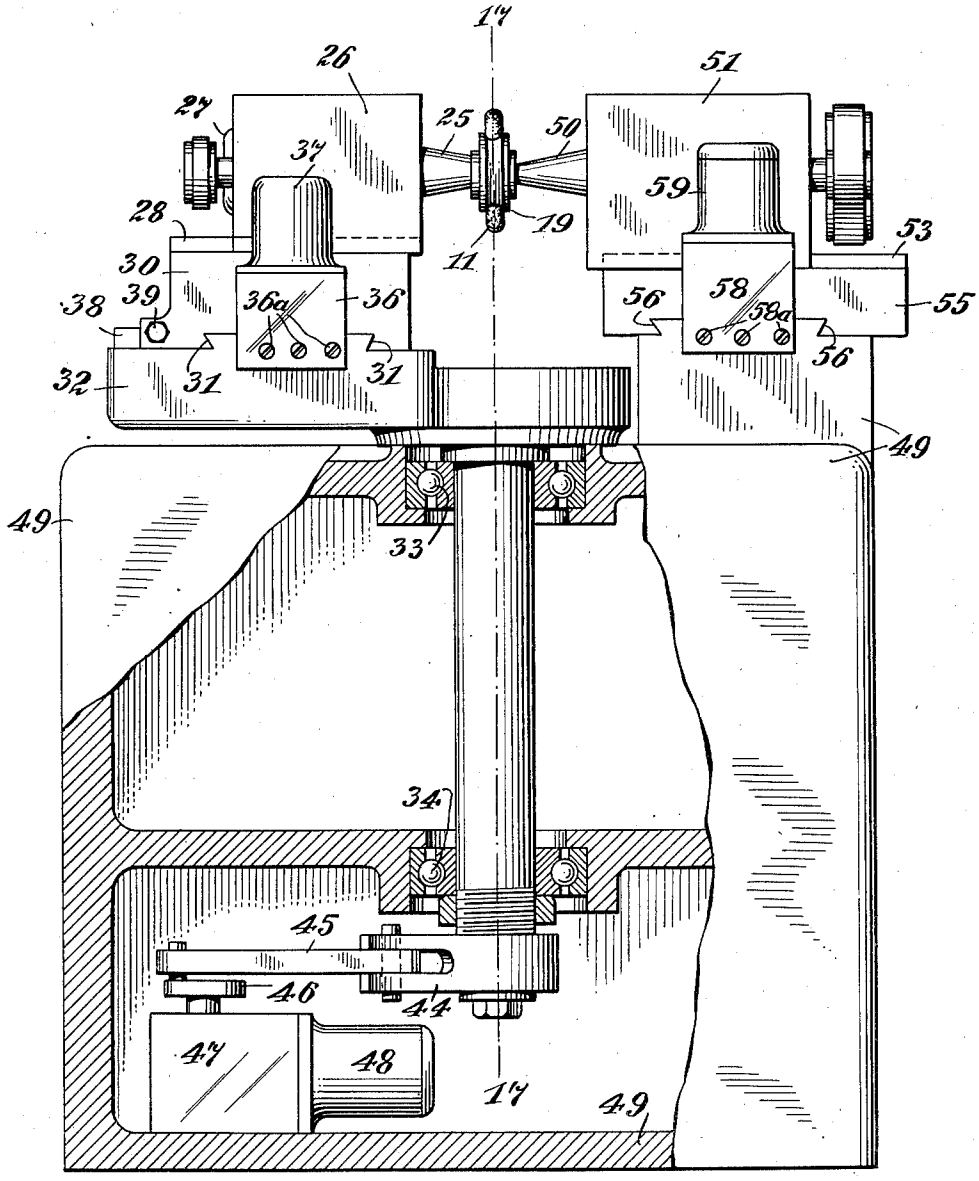
Jan. 18, 1949. W. D. ANDERSON 2,459,406

OSCILLATING RACEWAY GRINDER AND METHOD OF GRINDING RACEWAYS

Filed June 26, 1946 3 Sheets-Sheet 1

Fig. 1.



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OSCILLATING RACEWAY GRINDER AND METHOD OF GRINDING RACEWAYS

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Fig. 2.

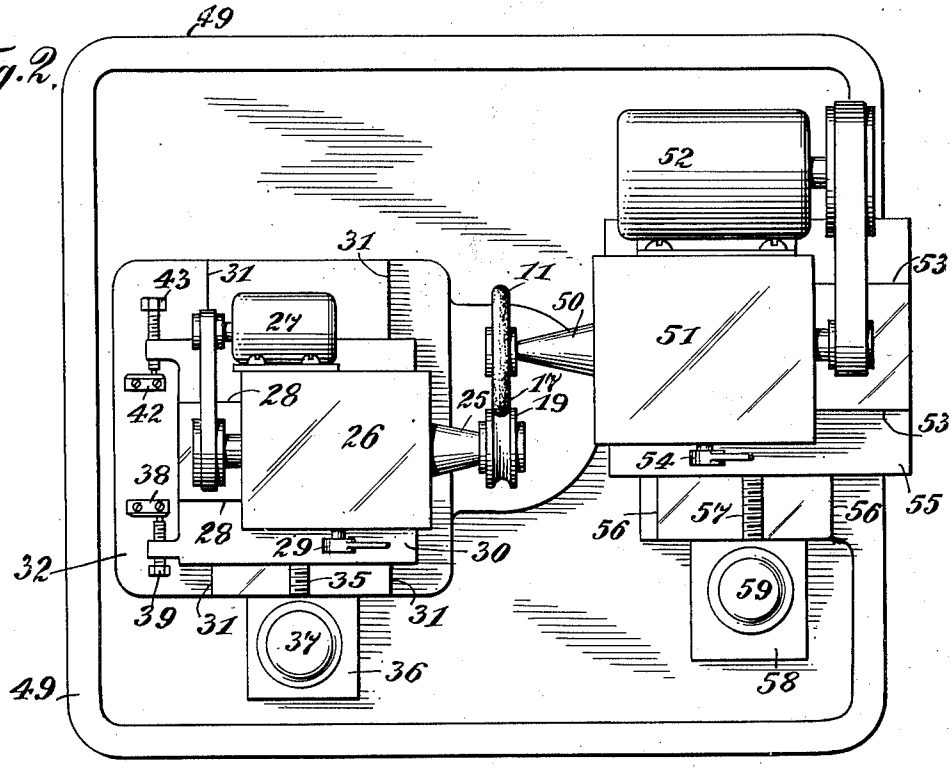
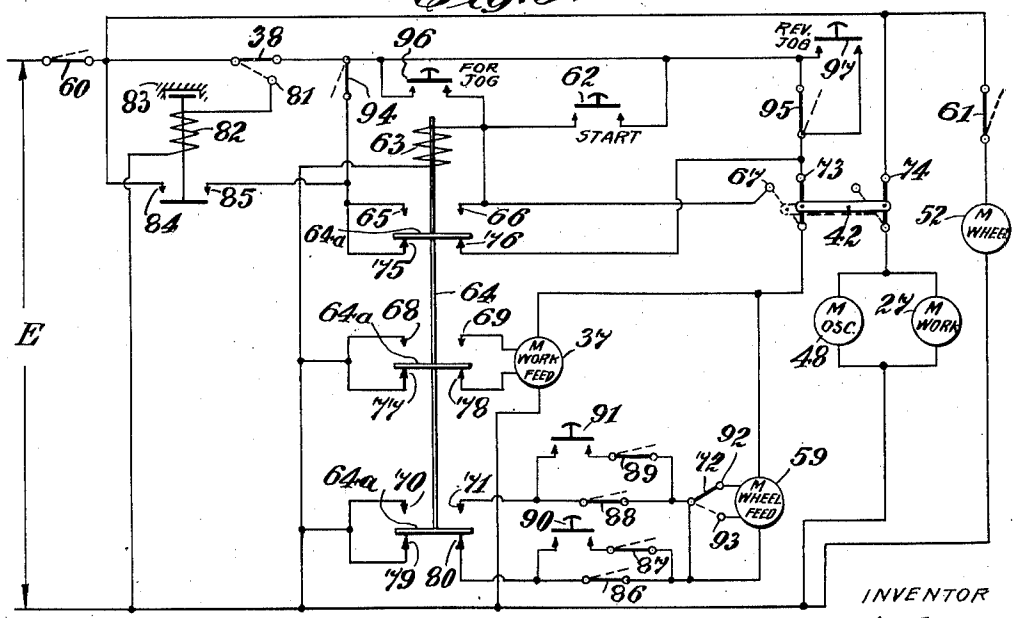


Fig. 3.



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OSCILLATING RACEWAY GRINDER AND METHOD OF GRINDING RACEWAYS

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Fig. 4.

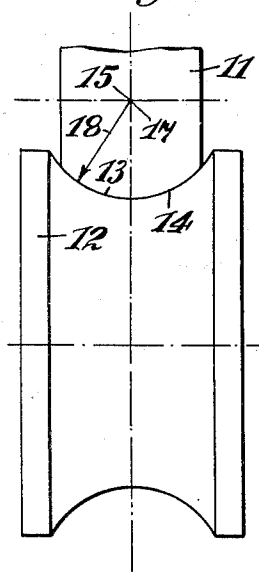


Fig. 5.

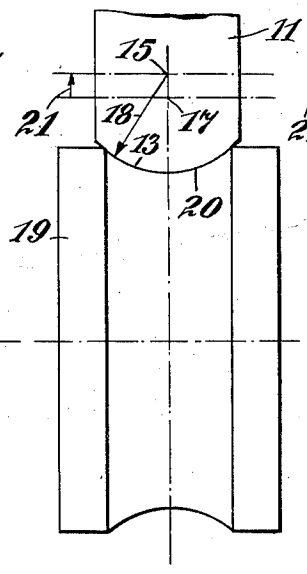


Fig. 6.

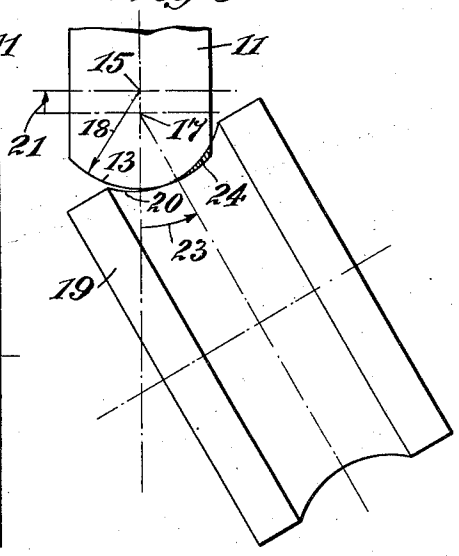


Fig. 7.

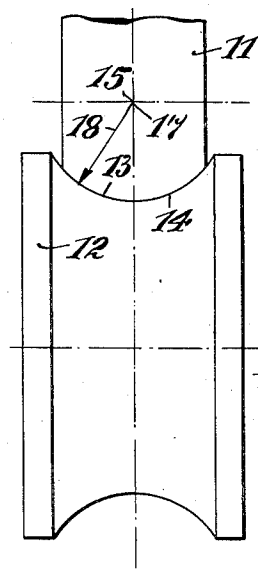


Fig. 8.

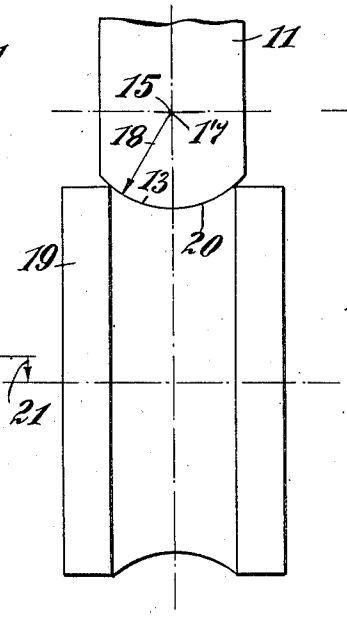
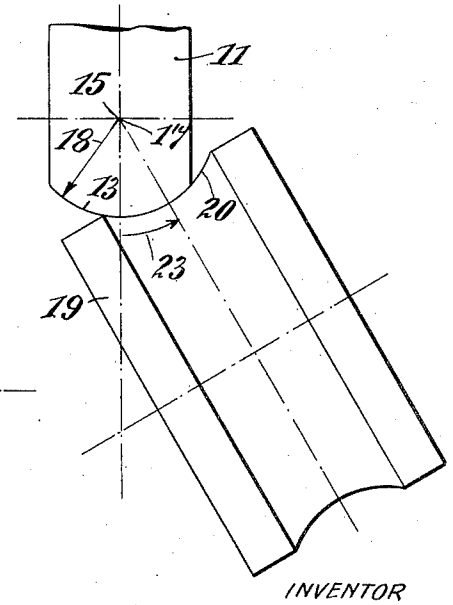


Fig. 9.



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UNITED STATES PATENT OFFICE

2,459,406

OSCILLATING RACEWAY GRINDER AND METHOD OF GRINDING RACEWAYS

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Application June 26, 1946, Serial No. 679,400

20 Claims. (Cl. 51—97)

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This invention relates to oscillating grinders of the type used for grinding the raceways of anti-friction bearings and to a method for grinding said raceways.

The object of this invention is to provide an improved apparatus for, and method of, grinding very accurate raceway contours. Raceway contour is defined as the curve of intersection between the raceway surface and a cutting plane defined by the parallel axes of the wheel spindle and the work spindle. Wheel contour is defined as the curve of intersection of the wheel periphery, adjacent to the workpiece, with the above plane. Center of oscillation is defined as the point where the axis of oscillation intersects the above plane.

The usual method of grinding ball bearing raceways on oscillating grinders constructed according to the prior art consists of mounting the workpiece on a workhead which rotates the workpiece about its central axis, and also oscillates the workpiece about an axis passing thru the center of curvature of the raceway, and simultaneously subjecting the raceway to the action of a grinding wheel. As the material of the raceway is ground away, the grinding wheel is fed continuously into the workpiece until the raceway is of the desired diameter and radius of curvature when the feeding action is stopped. The grinding wheel is then retracted from the raceway and the workpiece removed from the machine. A new workpiece is then mounted in the machine and the wheel is again fed towards the workpiece as previously described.

During the period when grinding is taking place, the oscillation of the raceway in contact with the wheel tends to dress the wheel to a circular contour, and also the wheel tends to grind the raceway to a circular contour. Ideally, the raceway contour should be a true circular arc when the grinding of the raceway is finished. Actually, however, it has been found in practice that raceways ground in this manner frequently deviate from a true circular arc by an amount sufficient to seriously impair the operation of a precision ball bearing in which the radius of curvature of the raceway contour is only a few percent greater than the radius of the ball used with the raceway.

On the basis of research, I have found that in

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oscillating grinders constructed according to the prior art, there is a factor in the basic geometrical relationship of the raceway, the grinding wheel and the center of oscillation, which tends to cause the previously mentioned errors in raceway contour.

This invention consists of an oscillating grinder in which both the workhead and wheelhead may be given feeding movements relative to the axis of oscillation, said feeding movements being provided to facilitate the grinding of very accurate raceway contours.

Various embodiments of this invention, and combination of parts, will be described hereinafter.

The invention also consists in the method of grinding antifriction bearing raceways in accurately repeated cycles, during which cycles the raceway is simultaneously rotated about its central axis and oscillated about a non-parallel axis, which consists in subjecting the raceway to a grinding action at a substantially fixed distance from the axis of oscillation.

The invention will be more fully described hereinafter, embodiments thereof shown in the drawings, and the invention will be finally pointed out in the claims.

In the accompanying drawings,

Fig. 1 is a front elevation and partial section of the grinder;

Fig. 2 is a plan view of a grinder embodying the invention;

Fig. 3 is a wiring diagram for the grinder;

Figs. 4, 5 and 6 are enlarged plan views of the workpiece and a portion of the grinding wheel showing the grinding geometry for the usual grinder constructed in accordance with the prior art.

Figs. 7, 8 and 9 are enlarged plan views of the workpiece and a portion of the grinding wheel showing the grinding geometry for an improved grinder constructed in accordance with this invention.

Similar characters of reference indicate corresponding parts throughout the various views.

Referring to the drawings, Fig. 4 shows the relative position of wheel 11 and workpiece 12 at the completion of grinding in an oscillating grinder, constructed according to the prior art. It will be assumed that as the result of diamond

dressing or other special manipulation, both wheel contour 13 and finished raceway contour 14 are true circular arcs having a common center of curvature 15 coincident with the center of oscillation 17. Both contours are coincident and of radius 18.

Let the wheel be withdrawn from the raceway and the work removed from the grinder. In Fig. 5 is shown a new workpiece 19 and wheel 11 as the grinding commences. The new workpiece 19 has a previously formed raceway 20 of radius 18. The center of wheel and raceway curvatures 15 is no longer coincident with the center of oscillation 17 but has been withdrawn a distance 21 from the center of oscillation. Distance 21 represents, approximately, the amount of stock which will be removed from the surface of raceway 20.

In Fig. 6, workpiece 19 has oscillated thru a counterclockwise angle 23 from the position shown in Fig. 5. This oscillation takes place about the center of oscillation 17, and, as shown, results in interference between raceway 20 and wheel contour 13 in the shaded region 24.

This interference causes a rapid breakdown of the wheel surface in the localized region 24 and also results in rapid removal of metal from the raceway surface in region 24, thus destroying the originally circular wheel contour 13 and raceway contour 20. A similar interference also occurs when the workpiece 19 oscillates thru a clockwise angle from the position shown in Fig. 5. These interference effects occur during each cycle of the oscillation, and their cumulative effect is to cause the wheel contour to become non-circular in shape. Actual experience and precise measurements of wheel contour have shown that the corrective action of the raceway oscillating in contact with the wheel, is frequently insufficient to bring the wheel contour back to a true circular shape with the result that the finished raceway contour is also non-circular.

I have discovered that the above described interference effects may be completely eliminated if the center of wheel curvature 15 is kept centered on the center of oscillation 17, and the work is then fed toward the center of oscillation. In Fig. 7, the relative position of wheel 11 and workpiece 12 is shown at the completion of grinding in an oscillating grinder constructed in accordance with this invention. It is again assumed that wheel contour 13 and finished raceway contour 14 are true circular arcs having a common center of curvature 15 coincident with the center of oscillation 17. Both contours are coincident and of radius 18.

Now, let the center of wheel curvature 15 remain centered on the center of oscillation 17, and withdraw the workpiece from the wheel and remove the workpiece from the grinder. Fig. 8 shows a new workpiece 19 and wheel 11 as grinding commences. The new workpiece 19 has a previously formed raceway 20 of radius 18. The center of wheel curvature 15 is coincident with the center of oscillation 17. However, the workhead 26, Fig. 2, and workpiece 19 are located at a distance 21 from the position shown in Fig. 7. Again the distance 21 represents approximately the amount of stock which will be removed from the surface of raceway 20.

In Fig. 9, the workpiece 19 has been oscillated thru a counterclockwise angle 23 from the position shown in Fig. 8. This oscillation takes place about the center of oscillation 17. However, it will be seen that there is now no localized interference between raceway 20 and wheel contour 13. Furthermore, during the entire grinding cycle, raceway 20 and wheel contour 13 maintain a truly circular shape.

Therefore an oscillating grinder constructed in accordance with this invention, eliminates one of the factors tending to cause non-circular raceway contours.

The preceding discussion has, for reasons of simplicity, not considered the effect of wheel wear. It would be entirely possible to grind a number of rings without compensating for wheel wear, however, wheel wear would cause radius 18, Fig. 7, to become progressively smaller. In actual practice, however, it is desirable to maintain radius 18 at a fixed value, and thus it is desirable to provide for a feeding movement of wheel 11 towards center of oscillation 17 to compensate for wheel wear.

Ideally, wheel 11 should be fed continuously towards center of oscillation 17 at exactly the same rate that wheel surface 13, Fig. 9, wears away, and thus the center of wheel curvature 15 would at all times be precisely coincident with center of oscillation 17. Practically, however, the wheel wears very slowly and particularly for large diameter wheels and small diameter workpieces an intermittent feeding of the wheel towards the center of oscillation may be substituted for the ideal continuous feed. Such an intermittent wheel feed might take place during a portion of the grinding time or might take place after one or more pieces had been ground, or might take place both during and after grinding. In any type of intermittent wheel feed it is evident that after the feed has taken place, the center of wheel curvature 15 will be separated from the center of oscillation 17 by a small distance equal to the amount of the wheel feed. Further, in order to minimize wheel and raceway interference effects, the distance between the center of wheel curvature 15 and center of oscillation 17 must be small relative to the total amount of stock removal corresponding to the distance 21. When the distance between the center of wheel curvature 15 and the center of oscillation 17 is small relative to the total amount of stock removal 21, the center of curvature 15 of the wheel contour will be defined as being substantially coincident with the center of oscillation 17.

Furthermore, this previous discussion has assumed that the raceway in the new workpiece 19 will always have an accurate contour of radius 18 and that this contour will always have its center of curvature at a common distance from the locating face of the ring. In actual practice this condition is frequently not realized since the raceway in the new workpiece 19 may be off center in one direction or the other, or may have a raceway contour which is not truly circular. For these and other reasons, it is evident that the initial contact between the raceway in the new workpiece 19 and wheel contour 13 may not be precisely coincident as shown in Figs. 8, and 9. In such a case, during the initial grinding of raceway 20 the wheel will wear to a non-circular contour which has not one center of curvature but many centers. In such a case, we cannot correctly say that the wheel contour has a center of curvature coincident with the center of oscillation. However, we can avoid the interference effects shown in region 24 of Fig. 6, if the distances between the center of oscillation 17 and successive grinding positions of the wheel axis, form an al-

ways decreasing sequence. In other words, successive grinding positions of the wheel axis will always be closer to the center of oscillation 17 than at any previous instant of time.

In grinders constructed according to the prior art, this requirement is not met since the distance from the grinding position of the wheel axis to the center of oscillation is increased by the amount 21 each time that a new workpiece is placed in the grinder. Grinding position of the wheel axis is defined as the position of the wheel axis at any time that grinding is taking place, as distinguished from a loading position of the wheel axis with the wheel moved back from the workpiece to facilitate mounting of the workpiece.

Physical research and precise measurements of raceway and wheel contours on a grinder constructed according to this invention, have shown that the wheel contour retains its original circular shape, and the resulting raceway contour is also truly circular within the limits of precision measurements.

As indicated in the previous discussion, the wheel contour and resulting raceway contour are intimately dependent upon the feeding motions of the work and wheel relative to the center of oscillation, therefore, if successive raceways are to have accurate contours of a fixed radius, it is essential that the feeding motions of the wheel and work must occur in accurately repeated cycles. In order to minimize variations in radius 18 and in order to minimize the previously described interference effect, it is necessary that during the grinding action the variation in the distance between the axis of oscillation and the region where the grinding is taking place, should be small relative to the total amount of stock removal represented by distance 21. In such a case the grinding action will be defined as occurring at a substantially fixed distance from the axis of oscillation.

The underlying concept of the improved method is then the subjection of the raceway to a grinding action at a substantially fixed distance from the axis of oscillation, in accurately repeated cycles, during which cycles the raceway is simultaneously rotated about its central axis and oscillated about a non-parallel axis.

To one skilled in the art, it will be evident that this invention may be embodied in various types of raceway grinders. Various methods of effecting and coordinating the feeding motions of the workpiece and wheel relative to the center of oscillation could be employed. For purposes of description, an embodiment of this invention is shown in Figs. 1, 2, and 3. The grinder shown has many features known to the prior art, and for reasons of simplicity, only those parts have been shown which are necessary for the description of the present invention.

Referring to Figs. 1 and 2, workpiece 19 is mounted on work spindle 25 which is mounted in suitable bearings in workhead 26, and is belt driven by work drive motor 27 which is fastened to workhead 26. Workhead 26 is laterally adjustable along dovetail ways 28 and may be clamped in position by screw clamp 29. Ways 28 are integral with work slide 30 which may be given a fore and aft feeding motion along dovetail ways 31 which are integral with oscillating table 32. Table 32 is supported by suitable bearings 33 and 34 to permit oscillation about the axis 17—17. The feeding motion of work slide 30 along ways 31 is effected by feed screw 35 which has one end threaded into work slide 30, and the other end positioned by a suitable thrust bearing in gear box 36, which is fastened to oscillating table 32 by screws 36a. Gear box 36 contains suitable reduction gears connecting the reversible, variable speed, work feed motor 37 to feed screw 35, as known and not shown.

Fastened to table 32 is a single pole, double throw limit switch 38, which is actuated on forward movement of work slide 30 by adjustable screw 39. Double pole, double throw limit switch 42 is fastened to table 32 and is actuated on reverse movement of work slide 30 by adjustable screw 43.

The oscillation of table 32 about axis 17—17, Fig. 1, is effected by lever 44, connecting rod 45 and eccentric 46, which is mounted on gear box 47, and is connected by suitable gears to oscillating drive motor 48, gear box 47 being fastened to base 49. These parts are known and not shown in detail.

Grinding wheel 11 is mounted on spindle 50 which is supported by suitable bearings in wheel head 51 and is belt driven by wheel drive motor 52 which is preferably mounted on wheel head 51. Wheel head 51 is laterally adjustable on dovetail ways 53 and may be clamped in position by screw clamp 54. Ways 53 are integral with wheel slide 55. Wheel slide 55 may be given a fore and aft feeding motion along dovetail ways 56 which are integral with base 49. The feeding motion of wheel slide 55 along ways 56 is effected by feed screw 57, which has one end threaded into wheel slide 55, and the other end positioned by a suitable thrust bearing in gear box 58. Gear box 58 is fastened to base 49 by screws or bolts 58a, and contains suitable reduction gears connecting feed screw 57 to the reversible, variable speed, wheel feed motor 59, known and not shown in detail.

The coordination of the various drive motors is accomplished by suitable electrical control circuits, as shown in the wiring diagram, Fig. 3. By suitably changing the control circuit, there are six distinct control cycles coordinating the feeding motions of workhead 26 and wheelhead 51 relative to the center of oscillation 17.

As a first type of coordinated control, consider the operation of the grinder with the control circuit arranged to provide automatic coordinated feed, and withdrawal of workpiece 19 relative to the center of oscillation 17, and concurrent feeding motion of wheel 11 towards the center of oscillation 17. Referring to the wiring diagram, Fig. 3, a suitable source of electric power is provided to impress a voltage E, as indicated in Fig. 3. Let single-pole, double-throw reversing switch 72 contact terminal 92 thus energizing the forward field of wheel feed motor 59, the "M" meaning motor in Fig. 3. Let switches 60, 61, 94, 95, 88 and 86 be closed and let switches 87 and 89 be open. Furthermore, let work slide 30 be in retracted position so that screw 43 holds double-pole, double throw, limit switch 42 in position to leave contacts 73 and 74 open.

With workpiece 19 in position, the operator starts the cycle by closing normally open momentary contact switch 62 thus energizing winding 63 of triple pole, double throw magnetic relay 64, thus lifting the relay armature and contact pieces 64a, and thus connecting contacts 65 to 66, 68 to 69 and 70 to 71. These connections provide a holding circuit thru winding 63, start work feed motor 37 in a forward direction to feed workpiece 19 towards center of oscillation 17, and

start wheel feed motor 59 in a forward direction to feed wheel 11 toward center of oscillation 17. As work slide 32 moves forward, screw 43 moves away from limit switch 42, thus completing circuits thru normally closed contacts 73 and 74, thus keeping motors 37 and 59 running, and starting oscillation drive motor 48 and work drive motor 27. The feeding motions of workpiece 19 and wheel 11 toward center of oscillation 17 continue during the grinding of raceway 20 until screw 39 actuates single-pole, double throw limit switch 38, and thus stops work feed motor 37 and wheel feed motor 59, and also breaks the holding circuit thru winding 63 thus allowing the relay armature to drop out and connect contacts 75 to 76, 77 to 78, and 79 to 80. Also, limit switch 38 completes a circuit thru contact 81 and winding 82 of pneumatic time-lag relay 83 having normally open contacts 84 and 85. The interval required for relay 83 to close, allows the grinding wheel to "spark-out." When relay 83 closes, it connects contacts 84 to 85, and thus provides a circuit thru contacts 75 to 76 to 73, and also provides another circuit thru contact 77 to 78, thus causing work feed motor 37 to run in a reverse direction and withdraw workpiece 19 away from center of oscillation 17. Also, a circuit is established between contacts 79 and 80, thus starting wheel feed motor 59 in a forward direction to provide further feed of wheel 11 toward center of oscillation 17, while the workpiece is withdrawing. The withdrawal movement of workpiece 19 continues until screw 43 actuates limit switch 42, thus stopping motors 37, 59, 27 and 48. The workpiece 19 is then removed from the grinder, and the raceway diameter measured on a suitable measuring instrument. If the raceway diameter is too large, it indicates that the wheel feed is insufficient to compensate for wheel wear, and consequently it is necessary to increase the speed of wheel feed motor 59. Conversely, if the raceway diameter is too small, the speed of wheel feed motor 59 must be decreased. Thus, by trial and error, the speed of wheel feed motor 59 is adjusted so that the amount of wheel feed will just compensate for the amount of wheel wear, and thus for successive raceways the wheel contour 13 and raceway contour 14 will have a fixed value for radius 18.

As a second type of coordinated control, consider the operation of the grinder with the control circuit arranged to provide automatic coordinated feed and withdrawal movements of workpiece 19 relative to center of oscillation 17 and a feeding movement of wheel 11 toward center of oscillation 17 during the grinding period only. Consider the circuit arrangement to be identical with that previously described, except let switch 86 be open. The operation of the grinder will be identical with the first type of operation except that when relay 83 closes to reverse the work feed motor, there will be no circuit thru switch 86 and thus wheel feed motor 59 will not provide any feeding motion of wheel 11 toward center of oscillation 17, while workpiece 19 is withdrawing from center of oscillation 17. As previously described, it will be necessary to make a trial and error adjustment of the speed of the wheel feed motor 59 in order that the amount of wheel feed will just compensate for wheel wear.

As a third type of coordinated control, consider the operation of the grinder with the control circuit arranged to provide automatic coordinated feed and withdrawal movements of workpiece 19 relative to center of oscillation 17, and a feeding movement of wheel 11 toward center of oscillation 17 during the withdrawal period only. Consider the circuit arrangement to be similar to that used for the first type of control, except let switch 88 be open. The operation of the grinder will be identical with the first type of operation, except that when winding 63 or relay 64 is energized there is no circuit thru switch 88 and consequently while workpiece 19 feeds toward center of oscillation 17, there is no feeding movement of wheel 11 toward center of oscillation 17. However, as soon as relay 83 closes to reverse work feed motor 37 and withdraw workpiece 19, wheel feed motor 59 will feed the wheel 11 toward center of oscillation 17. Again, the speed of wheel feed motor 59 should be regulated to just compensate for wheel wear.

The above described completely automatic grinding cycles are frequently desirable, since they permit one operator to load and unload several grinding machines with a resultant economy in labor cost per piece ground. However, under certain conditions of operation, it may be desirable to provide a semi-automatic control of the grinding wheel feed in order to permit modification of the grinding cycle in accordance with visual observation as the raceway is being ground.

As a fourth type of coordinated control, consider the operation of the grinder with the control circuit arranged to provide automatic coordinated feed and withdrawal movements of workpiece 19 relative to center of oscillation 17. However, the feeding movements of wheel 11 toward center of oscillation 17 will be manually controlled and will be coordinated to occur during either feeding or withdrawal movements of the work. Consider the circuit arrangement to be similar to that described for the first type of control, with the exception that switches 86 and 88 are open and switches 87 and 89 are closed. The operation of the grinder will be identical with that described for the first type of control, except that feeding movements of wheel 11 do not take place automatically. While winding 63 is energized and workpiece 19 is feeding toward center of oscillation 17, wheel feed may be controlled manually by depressing the normally open momentary contact switch 91. When workpiece 19 is withdrawing from center of oscillation 17, the feed of wheel 11 toward center of oscillation 17 may be manually controlled by depressing normally open momentary contact switch 90.

As a fifth type of coordinated control, consider operation of the grinder with the control circuit arranged to provide automatic coordinated feed and withdrawal movements of workpiece 19 relative to center of oscillation 17. However, the feed of wheel 11 toward center of oscillation 17 will be manually controlled and coordinated to take place only while workpiece 19 is feeding toward axis of oscillation 17. Consider the circuit arrangement to be similar to that for the first type of control, except that switches 86, 88 and 87 are open and switch 89 is closed. The operation of the grinder is identical with the first type of operation, except that no automatic feeding movements of the wheel occur and manual control of the wheel feed is possible by depressing normally open momentary contact switch 91, only while winding 63 is energized and workpiece 19 is feeding toward center of oscillation 17.

As a sixth type of coordinated control, consider operation of the grinder with the control circuit arranged to provide automatic coordinated feed and withdrawal movements of workpiece 19 relative to center of oscillation 17, and provision for a manually controlled feed of work 11 toward center of oscillation 17 only during the period that workpiece 19 is withdrawing from center of oscillation 17. Consider the circuit arrangement to be identical with that described for the first type of control, except that switches 86, 88 and 89 are open and switch 87 is closed. The operation of the grinder will be identical with the first type of operation, except that feeding movements of wheel 11 toward center of oscillation 17 are not automatic, but are manually controlled by depressing normally open momentary contact switch 90 during the period that workpiece 19 is withdrawing from center of oscillation 17.

Although not directly concerned with the grinding operation, the circuit shown in Fig. 3 incorporates a number of supplementary switches for use in setting-up and adjusting the grinder. With single-pole, double throw reversing switch 72 in position to contact terminal 93, it is evident that closing of switch 86 will cause the wheel feed motor 59 to reverse and thus withdraw wheel 11 from center of oscillation 17 to permit replacing a worn wheel with a new and larger wheel. Jogging movements of work feed motor 37 and work slide 30 may be effected by opening switches 94 and 95 and actuating normally open momentary contact switches 96 and 97 to cause forward and reverse jog movements respectively.

For reasons of clarity and brevity, this invention has been described with particular reference to the grinding of inner ring raceways for anti-friction bearings. However, the basic relationship concerning the geometry of the grinding wheel contour, raceway contour and center of oscillation apply equally well in the grinding of raceways for outer rings of anti-friction bearings, and therefore this invention applies to outer ring raceway grinders as well as inner ring raceway grinders.

Although the invention has been described in some detail with reference to a particular design of raceway grinder and a particular arrangement of control circuits, it is understood that this was done only by way of example, and that numerous changes in the details of construction and means of coordinating the feeding movements of the wheel and work relative to the center of oscillation may be resorted to without departing from the spirit of the invention as hereinafter claimed. For example the feeding and withdrawal movements of the workhead and wheelhead might be effected by pneumatic, hydraulic, or mechanical mechanism. Also, the feeding movement of the wheel toward the center of oscillation might be controlled by a suitable control circuit actuated by an automatic sizing device or switch responsive to the diameter of the raceway being ground, Numerous other modifications will be evident to one skilled in the art.

I have described several forms of my invention, but obviously various changes may be made in the details disclosed without departing from the spirit of the invention as set out in the following claims.

I claim:

1. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a mechanism for feeding the wheel relative to the axis of oscillation, and a control mechanism integral with the grinder for coordinating said feed mechanisms.

2. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a mechanism for feeding the wheel relative to the axis of oscillation, and a control means integral with the grinder for coordinating said feeding mechanisms to make the distances between the oscillation axis and successive grinding positions of the wheel axis form an always decreasing sequence.

3. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a mechanism for feeding the wheel relative to the axis of oscillation, and a control means integral with the grinder for coordinating said feed mechanisms to keep the center of curvature of the wheel contour substantially coincident with the oscillation axis while the workpiece is being ground.

4. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, and a mechanism, operative only while grinding is taking place, for feeding the wheel relative to the axis of oscillation.

5. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a mechanism, operative only while grinding is taking place, for feeding the wheel relative to the axis of oscillation, and a control means for coordinating said feed mechanisms to make the distances between the oscillation axis and successive positions of the wheel axis form an always decreasing sequence.

6. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a griding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a mechanism, operative only while grinding is taking place, for feeding the wheel relative to the axis of oscillation, and a control means for coordinating said feeding mechanisms to keep the center of curvature of the wheel contour substantially coincident with the oscillation axis while the workpiece is being ground.

7. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece rel-

ative to the axis of oscillation, and a mechanism, operative only after grinding has been completed, for feeding the wheel relative to the axis of oscillation.

8. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a mechanism, operative only after grinding has been completed, for feeding the wheel relative to the axis of oscillation, and a control means for coordinating said feeding mechanisms to make the distances between the oscillation axis and successive grinding positions of the wheel axis form an always decreasing sequence.

9. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a mechanism, operative only after grinding has been completed, for feeding the wheel relative to the axis of oscillation, and a control means for coordinating said feeding mechanisms to keep the center of curvature of the wheel contour substantially coincident with the oscillation axis while the workpiece is being ground.

10. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, and a power driven mechanism for feeding the wheel relative to the axis of oscillation.

11. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a power driven mechanism for feeding the wheel relative to the axis of oscillation, and a control means for coordinating said feeding mechanisms to make the distances between the oscillation axis and successive grinding positions of the wheel axis form an always decreasing sequence.

12. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a power driven mechanism for feeding the wheel relative to the axis of oscillation, and a control means for coordinating said feeding mechanisms to keep the center of curvature of the wheel contour substantially coincident with the oscillation axis while the workpiece is being ground.

13. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, and a power driven mechanism, operative only while grinding is taking place, for feeding the wheel relative to the axis of oscillation.

14. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a power driven mechanism, operative only while grinding is taking place, for feeding the wheel relative to the axis of oscillation, and a control means for coordinating said feeding mechanisms to make the distances between the oscillation axis and successive grinding positions of the wheel axis form an always decreasing sequence.

15. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a power driven mechanism, operative only while grinding is taking place, for feeding the wheel relative to the axis of oscillation, and a control means for coordinating said feeding mechanisms to keep the center of curvature of the wheel contour substantially coincident with the oscillation axis while the workpiece is being ground.

16. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, and a power driven mechanism, operative only after grinding has been completed, for feeding the wheel relative to the axis of oscillation.

17. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a power driven mechanism, operative only after grinding has been completed, for feeding the wheel relative to the axis of oscillation, and a control means for coordinating said feeding mechanisms to make the distances between the oscillation axis and successive grinding positions of the wheel axis form an always decreasing sequence.

18. In an oscillating raceway grinder having a workhead rotating a workpiece, a wheelhead rotating a grinding wheel, and a power driven mechanism for oscillating the workpiece about an axis of oscillation, the combination of a power driven mechanism for feeding the workpiece relative to the axis of oscillation, a power driven mechanism, operative only after grinding has been completed, for feeding the wheel relative to the axis of oscillation, and a control means for coordinating said feeding mechanisms to keep the center of curvature of the wheel contour substantially coincident with the oscillation axis while the workpiece is being ground.

19. In an oscillating raceway grinder in which an anti-friction bearing raceway is simultaneously rotated about its central axis, oscillated about a non-parallel axis, and subjected to the action of a grinding wheel, the combination of means giving the raceway a feeding motion towards the axis of oscillation, means giving the grinding wheel a feeding motion towards the axis of oscil-

lation, and means simultaneously regulating both the raceway and the grinding wheel feeding motions proportional to the respective rates of wear of the raceway and grinding wheel, so that the grinding action occurs at a substantially fixed distance from the axis of oscillation.

20. The method of grinding anti-friction bearing raceways during which the raceway is simultaneously rotated about its central axis, oscillated about a non-parallel axis, and subjected to the action of a grinding wheel, which consists in subjecting the raceway to the grinding action at a substantially fixed distance from the axis of oscillation, and subjecting under positive control the raceway and the grinding wheel each to a movement towards the axis of oscillation proportional to the respective rate of wear of the raceway and grinding wheel, whereby grindings of successive raceways take place in accurately repeated cycles.

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