May 19, 1964 R. M. CHAPMAN 3,133,383

BALL GRINDING AND LAPPING MACHINE

Filed June 12, 1961 3 Sheets-Sheet 1

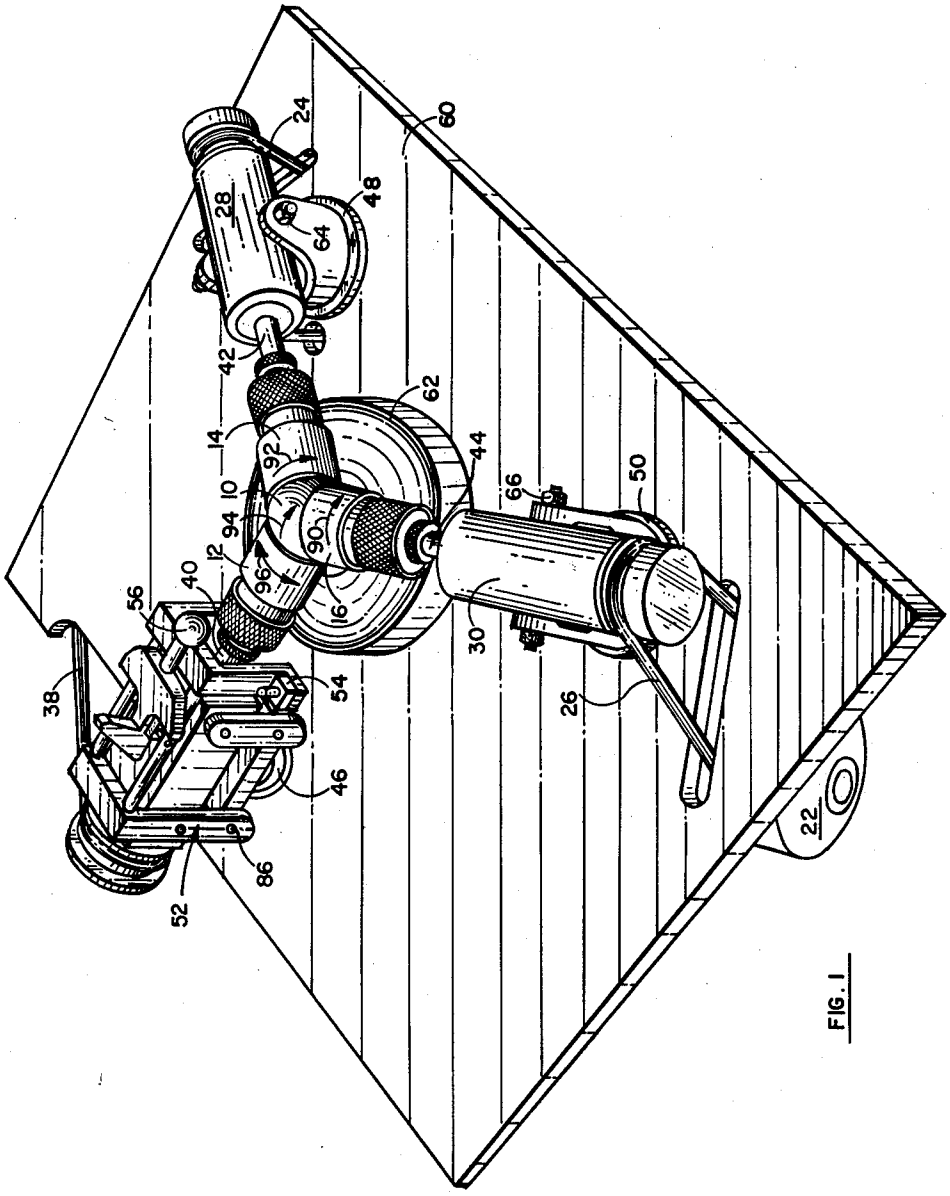


FIG. 1

INVENTOR.
RICHARD M. CHAPMAN

BY
Ernest L Brown
ATTORNEY

May 19, 1964 R. M. CHAPMAN 3,133,383

BALL GRINDING AND LAPPING MACHINE

Filed June 12, 1961 3 Sheets-Sheet 2

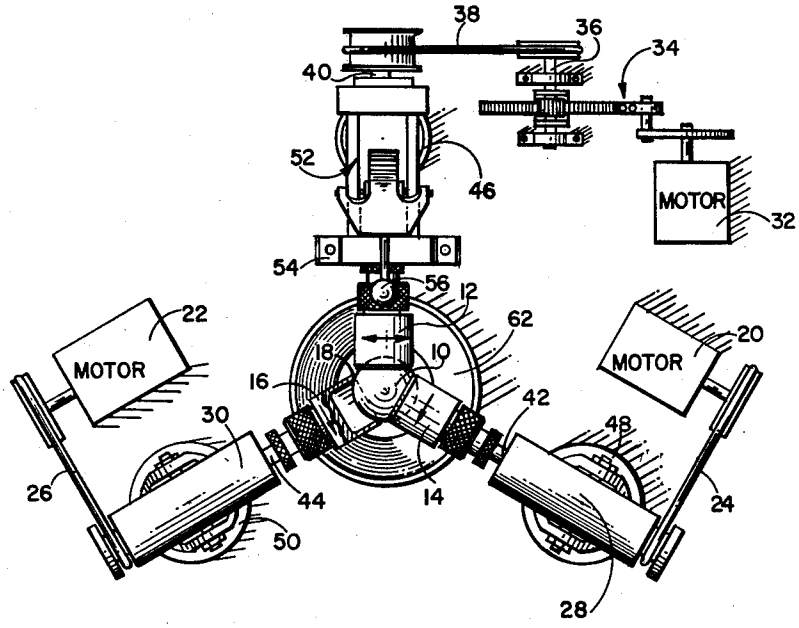


FIG. 2

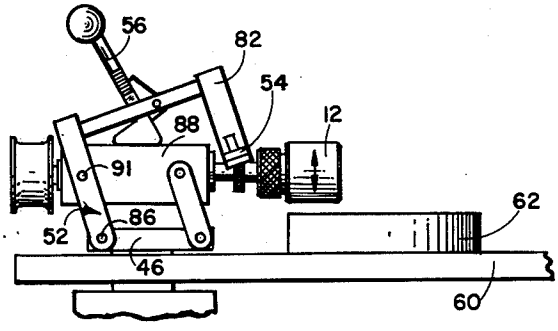


FIG. 6

INVENTOR.
RICHARD M. CHAPMAN

BY

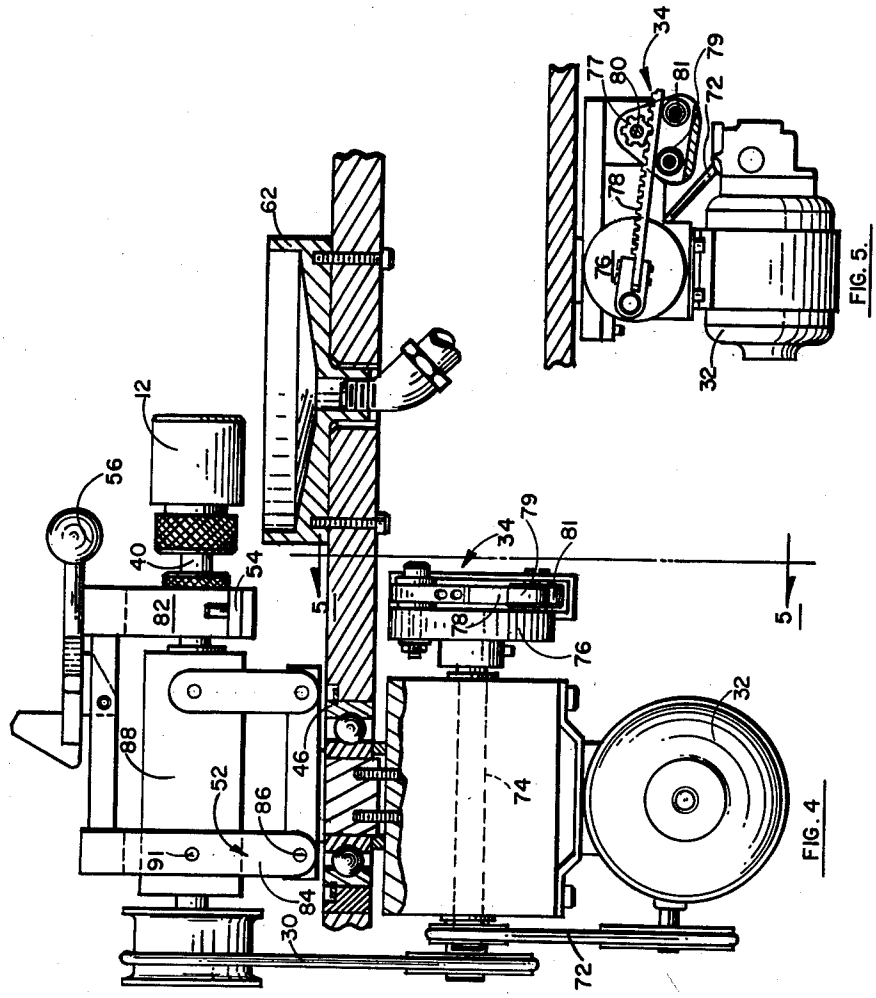
Ernest L Brown

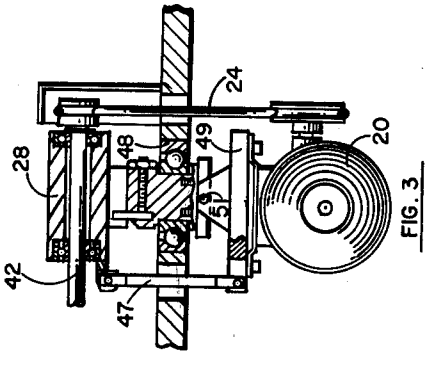
ATTORNEY

May 19, 1964 R. M. CHAPMAN 3,133,383

BALL GRINDING AND LAPPING MACHINE

Filed June 12, 1961 3 Sheets-Sheet 3





INVENTOR.
RICHARD M. CHAPMAN

BY

Ernest L Brown
ATTORNEY

United States Patent Office 3,133,383 Patented May 19, 1964

3,133,383

BALL GRINDING AND LAPPING MACHINE

Richard M. Chapman, Arcadia, Calif., assignor to North American Aviation, Inc.

Filed June 12, 1961, Ser. No. 116,331
8 Claims. (Cl. 51—117)

This invention pertains to a means for precisely grinding, lapping, and smoothing the surface of a spherical or truncated spherical ball. More particularly, the device of this invention is adapted to grind and lap the surface of a metallic ball to make it precisely round and smooth.

In modern instrument manufacturing it is frequently necessary to grind and polish spherical surfaces to a high degree of circularity and smoothness. For example, certain gyroscopes have their rotors spun upon air bearings whose surfaces must be precisely spherical to allow slight precession of the rotor. Usually the spherical rotor surface is a truncated spherical surface.

The surface may in small quantities, be ground, lapped, and polished by hand.

It has been necessary to manufacture spherical and truncated spherical sunrfaces in quantity lots. Prior known machines could not grind and lap the spherical surface of the required balls with sufficient roundness and smoothness.

The machine of this invention is adapted speedily and accurately to grind, lap, and polish the spherical portions of the surface of a ball.

It is therefore, an object of this invention to grind, lap, or polish the surface of a spherical member.

It is a more particular object of this invention to grind, lap, or polish the surface of a spherical ball.

It is also a more particular object of this invention to grind, lap, or polish the surface of a truncated spherical ball.

More particularly, it is the object of this invention to perform the above named objects with extreme accuracy of roundness and smoothness of the spherical member.

It is likewise a particular object of this invention simultaneously to rotate and lap, grind, or polish a spherically shaped surface on zonal surfaces of the sphere with an oscillating random grinding motion.

Other objects will become apparent from the following description taken in connection with the accompanying drawings in which:

FIG. 1 is an isometric view of a typical embodiment of this invention;

FIG. 2 is a plan view, partially in schematic, of the device of FIG. 1;

FIG. 3 is a view, partially in section, of a typical means for rotating the grinding cups used in this invention;

FIG. 4 is a view, partially in section, of a typical oscillating grinding cup used in this invention;

FIG. 5 is a view, partially in section, taken at 5—5 in FIGURE 4; and

FIG. 6 is a profile view of the oscillating member of FIG. 4 shown in its retracted position.

Referring to the figures, a spherical or truncated spherical ball **10** is contacted by three cup members **12**, **14**, and **16**. Each of cup members **12**, **14**, and **16** contact ball **10** on a circular surface, i.e., a line or zonal surface contact, one of which is shown at **18** in FIG. 2. A grinding or lapping compound (not shown) is applied to ball **10** to cause the internal surfaces of cups **12**, **14**, and **16** to grind or lap ball **10** in the zonal region of contact. Cups **14** and **16** rotate in a direction to reinforce each other in the torque they apply to ball **10**. Grinding cup **12** rotatably oscillates about the polar axis of its zonal contact region (preferably through 360 degrees) to cause various portions of ball **10** randomly to contact the grinding surfaces of cups **12**, **14**, and **16**.

Cups **14** and **16** are driven by motors **20** and **22** through belt drives **24** and **26** and through bearings **28** and **30**. It is to be stressed that cups **14** and **16** may conveniently be driven by a single prime mover. In FIG. 3, belt **24** drives spindle **42** in universally mounted bearing **28**. To maintain tension in belt **24** and to prevent belt **24** from moving bearing **28**, motor **20** is mounted upon a frame **49** which is pinned for rotation at **51**. A strut **47** between bearing **28** and frame **49** force-balances the tension of belt **24** to remove torque from the outer structure of bearing **28**.

The oscillation of cup **12** about the polar axis of its zonal contact area is caused by motor **32** which drives the bell-crank mechanism **34** to cause shaft **36** to oscillate through a complete turn about its axis of rotation. Shaft **36**, through belt **38**, drives spindle **40** and grinding cup **12**.

In the preferred embodiment of this invention three cups, substantially in the same plane are symmetrically disposed (120 degrees apart) about ball **10**. Although three grinding cups **12**, **14**, and **16** are sufficient to achieve the desired results, it is apparent that additional cups can be utilized.

Each spindle **40**, **42**, and **44** is connected rotatably to drive spindles **12**, **14**, and **16**, respectively in rotation about the polar axes of the zonal surfaces of contact betwen the grinding cups and ball **10**.

Spindles **42** and **44** are universally mounted to allow grinding cups **14** and **16** to seek their own angular positions upon the surface of ball **10**. In the embodiment of FIG. 1 spindles **42** and **44** are mounted in journal bearings **28** and **30** for complete rotation about the polar axes of the zonal grinding surfaces of cups **14** and **16**. The remaining two degrees of freedom are about the axes of shafts **64** and **66** and the axes of trunnions **48** and **50**. It is to be emphasized that other types of universal mountings may be employed. For example (in an embodiment not shown) spindles **42** and **44** could be spline-driven and universally mounted upon a ball type thrust bearing.

A parallel linkage **52** is adapted to retract grinding cup **12** from ball **10** to allow ball **10** to be removed. Parallel linkage **52** also is adapted to apply force to ball **10** to cause ball **10** to engage the zonal grinding surfaces of cups **12**, **14**, and **16**. Parallel linkage **52** is shown in FIG. 1 with the grinding cup **12** engaging ball **10** and in FIG. 6 with grinding cup **12** retracted from ball **10**. In FIG. 1 the weight of linkage **52** biases grinding cup **12** into engagement with ball **10**. Additional weights **54** optionally may be utilized to increase the force between grinding cup **12** and ball **10**. A locking member **56** conveniently may be used to lock grinding cup **12** into its retracted position against the torque applied by weight **54**.

In FIG. 1, the device of this invention is shown sitting on a table **60** with an oil sump **62** immediately below ball **10** to catch drippings therefrom. Spindles **42** and **44** are shown universally mounted upon shafts **64** and **66** and swivel bearings **48** and **50**.

In FIG. 4, bellcrank mechanism **34** is driven through a pulley arrangement **72** by motor **32**. The structure of the bellcrank mechanism may be better understood by referring to FIG. 5.

In FIG. 5, motor **32**, through pulley **72**, drives the shaft **74** of bellcrank **76**. Bellcrank **76** drives rackgear **78** which engages gear **77** on the shaft **80**. Rackgear **78** rides upon rollers **79** and **81**. Shaft **80** drives belt **38** which, in turn, drives spindle **40** and grinding cup **12**.

It is to be understood that grinding cup **12** may have axial force applied to it and it may be retracted parallel to the polar axis of the zonal grinding surface by mechanisms other than the parallel linkage mechanism **52**.

The parallel linkage mechanism **52** may be examined more closely by referring to FIGS. 4 and 6. In FIG. 4, latch **56** is disengaged which causes weight **54** and the unbalanced structure of the cantilevered weight support **82** to apply an unbalanced torque to lever **84** about pivot **86**. Lever **84** is connected to journal bearing **88** at pin **90**. Bearing **88** supports spindle **40** to cause force applied by pin **90** to be directly axially along spindle **40** and to grinding cup **12** along the polar axis of the zonal contact region thereof.

In FIG. 6, weights **54** and the unbalanced portion **82** or parallel linkage **52** are forced upward which forces, through pin **91**, bearing **88** to be retracted from ball **10**. The retraction of bearing **88** also retracts grinding cup **12**.

In operation, grinding cup **12** is retracted into the position shown in FIG. 6. A ball or truncated ball to be ground **10** is inserted into the zonal cups **14** and **16**. Latch **56** is then disengaged to allow the weight **54** and the unbalanced portion **82** of linkage **52** to force grinding cup **12** into engagement with ball **10**. Power is then applied to motors **20**, **22**, and **32**. It is to be understood that one motor could be utilized, together with appropriate linkages, to drive spindles **42** and **44** and bellcrank mechanism **34**. Abrasive compound (not shown) is then applied to ball **10**. The drippings are caught in sump **62**. The rotation of grinding cups **14** and **16** about polar axes of their zonal contacting grinding surfaces in the direction shown by arrows **90** and **92** causes the torque transmitted to ball **10** to move ball **10** in the direction shown by arrow **94**. That is to say, the directions of arrows **90** and **92** are such that the torques applied by cups **14** and **16** reinforce to rotatably drive ball **10** in the direction shown by arrow **94**. The operation of bellcrank mechanism **34** causes cup **12** rotatably to oscillate, preferably 360 degrees, about the polar axis of its zonal grinding surfaces, as shown by arrow **96**. Because of the variable friction between the grinding cups and ball **10**, ball **10** is caused to move randomly relative to the grinding cups which causes ball **10** to be uniformly rounded and smoothed.

When the grinding of ball **10** is completed, latch **56** is moved into the position shown in FIG. 6, which retracts grinding cup **12** from ball **10** and allows ball **10** to be released.

Thus, the device of this invention is a grinding machine which is particularly adapted precisely to grind and lap spherical balls to create a ball of precise curvature and smoothness.

Although the device of this invention has been described particularly above it is to be understood that the invention is not to be limited by the above description but only in accordance with the spirit and scope of the appended claims.

I claim:

1. Means for grinding a spherical surface comprising: at least three grinding cup members each shaped to have substantially the same curvature and positioned to engage a spherical surface in a plurality of zonal regions; mechanical means for rotatably oscillating at least one said cup member about a polar axis of its said zonal region, mechanical means for rotating the remaining said cup members; and mechanical force means connected to one of said cup members for urging said one of said cup members against said spherical surface and urging said spherical surface against the other of said cup members.

2. Means for grinding a spherical surface comprising: first, second, and third grinding cup members each shaped to have substantially the same curvature and positioned to engage a spherical surface in a first, second, and third zonal region; mechanical means for automatically rotatably oscillating at least one said cup member about a polar axis of its said zonal region, mechanical means for automatically rotating the remaining two cup members in directions to cause random grinding of said spherical surface, and means for mechanically applying an axial force to at least one of said cup members.

3. Means for grinding a spherical surface comprising: first, second, and third grinding cups each shaped to have substantially the same curvature and positioned to engage and support a spherical object in a first, second, and third zonal region; mechanical means for rotating two of said cups about the polar axes of their respective zonal grinding regions, means for supporting said two of said cups for universal freedom of rotation, and mechanical means for rotatably oscillating said remaining cup that is not rotated, about the polar axis of its zonal grinding region.

4. Means for grinding a spherical surface comprising: first, second, and third grinding cups each shaped to have substantially the same curvature and positioned to engage and support a spherical object in first, second, and third zonal regions; mechanical means for rotating said first and second cups about the polar axes of their respective zonal regions in directions to reinforce each other in the torque transmitted from said cups to said object; means for supporting said first and second cups with universal freedom of rotation; and mechanical means for rotatably oscillating said third cup about its polar axis.

5. Means for grinding a spherical surface comprising: first, second, and third grinding cups each shaped to have substantially the same curvature and positioned to engage and support a spherical object in first, second, and third zonal regions, the polar axes of said regions being substantially coplanar; mechanical means for rotating said first and second cups about the polar axes of their respective zonal regions, in directions to reinforce each other in the torque transmitted from said cups to said object; and mechanical means for rotatably oscillating said third cup about its said polar axis.

6. Means for grinding a spherical surface comprising: first, second, and third grinding cups each shaped to have substantially the same curvature and positioned to engage and support a spherical object in first, second, and third zonal regions, the polar axes of said zonal regions being substantially coplanar and displaced substantially 120° apart; means for rotating said first and second cups, about the polar axes of their respective zonal regions, in directions to reinforce each other in the torque transmitted from said cups to said object; means for rotatably oscillating said third cup about its polar axis; two of said cups being pivoted for universal freedom of rotation, and said third cup being pivoted for freedom of rotation about an axis substantially perpendicular to the plane of said polar axes and adapted to translate along its said polar axis.

7. A device as recited in claim 6 and further comprising means for applying a force to said translatable cup, controllably to urge said translatable cup towards said object to force said object into engagement with said cups.

8. Means for grinding a spherical surface comprising: first, second, and third grinding cups, each shaped to have substantially the same curvature and positioned to engage and support a spherical object in first, second, and third zonal regions, the polar axes of said regions being substantially coplanar and circumferentially displaced about said objects in a substantially symmetrical pattern; means for rotating said first and second cups, about the polar axes of their respective zonal regions, in directions to reinforce

each other in the rotation torque transmitted from said cups to said object; means, including a bell-crank mechanism, for rotatably oscillating said third cup about its polar axis; said first and second cups being adapted to pivot for freedom of rotation about parallel axes perpendicular to the plane of said polar axes; said third cup being adapted to translate along its polar axis; and force means, connected to said third cup to apply a force to said third cup along its polar axis to urge said third cup into engagement with said objects and force said object into engagement with said first and second cups.

References Cited in the file of this patent

UNITED STATES PATENTS

1,042,794	Irwin	Oct. 29, 1912
2,787,093	Sundberg	Apr. 2, 1957
3,024,578	Mushkin	Mar. 13, 1962

OTHER REFERENCES

"Making Crystal Spheres" from Review of Scientific Instruments, vol. 25, 1954, page 401. Copies in Scientific Library and Div. 58 (51–289).