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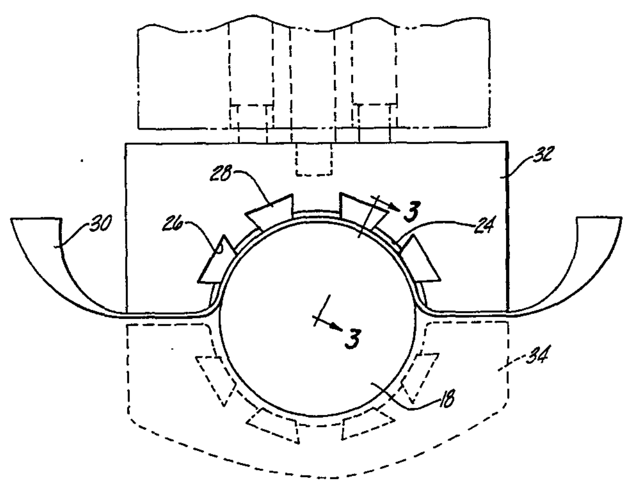
(54) **Improved microfinishing apparatus and method.**

(57) A microfinishing apparatus and method is disclosed particularly useful for microfinishing workpiece surfaces such as are found in journal bearings and cylinder bores. This invention improves over conventional machines and methods wherein coated abrasive tape is brought into contact with a relatively rotating workpiece surface and is pressed against that surface by an elastomeric plastic insert. According to this invention, the insert is made from a relatively rigid substance such as honing material stone. Since the insert is made from a rigid material, the insert surface shape is generated in the workpiece surface and therefore geometry corrections in the workpiece surface can be accomplished. In alternate embodiments of this invention, the rigid inserts have relieved portions or noncylindrical surfaces such that a desired surface profile in the workpiece surface is generated. In another embodiment, one or more flexible inserts are added to the rigid insert enabling the fillet radius area to be microfinished. In yet another embodiment, coated abrasive tape includes a multiplicity of perforations thereby permitting the exchange of cutting fluids between the surfaces. Finally, several means for supporting the rigid inserts for slight rotation relative to the workpiece surface are described.



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IMPROVED MICROFINISHING APPARATUS AND METHOD

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates to metal surface finishing and particularly to an improved apparatus and method for microfinishing metal surfaces using coated abrasive tape materials.

Numerous types of machinery components must have finely controlled surface finishes in order to perform satisfactorily. For example, surface finish control, also referred to as microfinishing, is particularly significant in relation to the manufacturing of journal bearing and cam surfaces such as are found in internal combustion engine crankshafts, camshafts and power transmission shafts and any other finished surface. For journal type bearings, very accurately formed cylindrical surfaces are needed to provide the desired bearing effect which results when lubricant is forced between the journal and the associated bearing. Improperly finished bearing surfaces may lead to premature bearing failure and may limit the load carrying capacity of the bearing.

Currently, there is a demand for higher control of journal bearing surfaces by internal combustion engine manufacturers as the result of; greater durability requirements necessary to offer improved product warranties, the higher operating speeds at which engines (particularly in motor vehicles) are now required to sustain, and the greater bearing loads imposed through increased efficiency of engine structures.

In addition to bearing structures, surface finish control must be provided for engine cylinder walls in order to provide the desired oil and gas seal with the piston rings. Numerous other types of machine components also require controlled surface finishes, particularly along areas of sliding contact between parts.

Microfinishing has primarily been accomplished according to the prior art using two different types of machining techniques. In stone microfinishing, a stationary honing stone is brought against the desired surface. When microfinishing cylindrical journal bearing surfaces, the honing stone is caused to oscillate traversely from one edge of the journal to another as the workpiece is rotated with respect to the stone. This process possesses a number of significant disadvantages. Due to the requirement that the honing stone be soft enough to be self-dressing and to provide the desired material removal characteristics, the stone, through use, takes on the shape of the part being finished. Therefore, this method, instead of correcting geometry variations in the part being microfinished, actually causes such variations to occur. Additionally, since honing stones are perishable, they must be frequently replaced and redressed. Finally, it is extremely difficult to find honing stones with consistent qualities resulting in significant differences in the finished parts when machined by different stones.

Another significant disadvantage of stone microfinishing of journal bearings using a honing stone is the fact that, since the journals generally include outwardly projecting radius edges, the stone cannot laterally overstroke portions of the surface being machined which leads to uneven stone wearing. Such uneven wearing causes a change in the profile shape of the honing stone, and this shape is consequently generated in subsequent parts being machined. Finally, since the honing stone generally has sharp corner edges, it cannot be used to microfinish near the radius edges of the bearing surface.

In another microfinishing process, herein referred to as conventional coated abrasive tape microfinishing, the surface being finished is caused to rotate and a coated abrasive tape is brought into contact under pressure with this surface. As the part is rotated, the abrasive material reduces the roughness of the surface. In the conventional process, the tape is brought into contact with the rotating surface by pressure exerted by compressible elastomeric inserts, typically made from urethane plastic compounds. The conventional coated abrasive tape microfinishing process overcomes several of the disadvantages associated with stone microfinishing. This process is capable of microfinishing in the journal fillet radius area since the tape is relatively flexible. In addition, this process uses a renewable abrasive surface which can be purchased having consistent qualities. This process, however, does not overcome other disadvantages of stone microfinishing. Principal among these disadvantages of this process is the fact that the process does not correct geometry variations in the part being microfinished, since the insert backing the coated abrasive tape is a flexible material and therefore, the tape conforms to the surface profile of the component surface being machined.

In view of the above-described shortcomings of microfinishing devices and methods according to the prior art, it is a principal object of this invention to provide a microfinishing apparatus and method which is capable of correcting geometry imperfections in finished surfaces. It is an additional object of this invention to obviate the necessity of redressing or replacement of the primary cutting tool in microfinishing operations. It is yet another object to consistently produce surfaces having smoothness characteristics superior to those achievable by conventional means.

The above principal objects of this invention are provided by a microfinishing system which employs an abrasive coated tape which is brought into contact with a rotating workpiece, and is pressed into contact by that workpiece by a rigid backup insert. This rigid insert does not cause the abrasive tape to conform to the surface profile of the workpiece. Instead, the rigid insert causes greater abrasive tape contact pressure to be applied to portions of the workpiece surface which extend beyond the desired surface, thereby causing greater material removal in those areas. This system therefore permits the microfinishing system to correct geometry imperfections in the workpiece. Since the insert is not the primary cutting tool, it is not subject to significant changes in profile with use. With appropriate additional components, the rigid inserts may be provided with the capability of polishing fillet radius areas. The microfinishing system according to this invention has been found to provide a significant advance in the art of microfinishing enabling consistent production of surface finishes unachievable using the devices and processes according to the teachings of the prior art.

Additional benefits and advantages of the present invention will become apparent to those skilled in the art to which this invention relates upon a reading of the described preferred embodiments of this invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a pictorial view of a crankshaft being rotated such that one of its pin journals is being microfinished by the clamping of a polishing shoe assembly against the pin journal;

Figure 2 is a cross-sectional view taken through a polishing shoe assembly according to the prior art;

Figure 3 is a cross-sectional view taken along line 3-3 of Figure 2;

Figure 4 is a cross-sectional view of a polishing shoe assembly according to the subject invention;

Figure 5 is a cross-sectional view taken along line 5-5 of Figure 4;

Figure 6 is a second embodiment of this invention employing a rigid back-up insert having relieved portions;

Figure 7 is a cross-sectional view taken along line 7-7 of Figure 6;

Figure 8 shows a third embodiment of this invention using a modified rigid back-up insert;

Figure 9 is a cross-sectional view taken along line 9-9 of Figure 8;

Figure 10 illustrates a fourth embodiment of this invention wherein a rigid back-up insert is used with flexible inserts such that the fillet radius portions may be microfinished;

Figure 11 shows a fifth embodiment of this invention wherein solid back-up inserts are used in conjunction with a perforated coated abrasive tape which enhances lubricant flow to the surface being microfinished;

Figure 12 shows a sixth embodiment of this invention wherein an alternate means of mounting the polishing shoe assembly is shown;

Figure 13 shows a seventh embodiment of this invention wherein an elastomeric insert is provided to polish the filet radius and side wall portions of a workpiece; and

Figure 14 is a cross-sectional view taken along line 14-14 of Figure 13 particularly showing the elastomeric insert according to this embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

A polishing shoe assembly is shown by Figure 1 and is designated there by reference character 10. Polishing shoe assembly 10 is shown with the associated support mechanisms shown schematically and is shown in position to microfinish a bearing surface of an internal combustion engine crankshaft. As is shown by that Figure, crankshaft 12 is supported at opposing ends by headstock 14 and tailstock 16 which together cause the crankshaft to be rotated about its longitudinal center axis. Crankshaft 12 includes a plurality of cylindrical bearing surfaces which must be microfinished including pin bearings 18 which, in use, becomes connected to a piston connecting rod; and main bearings 20, which support the crankshaft for rotation within the engine block. Polishing shoe assembly 10 is shown mounted to arm 22. Polishing shoe assembly 10 is caused to oscillate laterally along the surface being machined by oscillating the shoe assembly, or by oscillating the workpiece relative to the shoe assembly. Arm 22 permits polishing shoe assembly 10 to orbit with pin bearing 18 since that bearing journal is positioned eccentrically with respect to the center of rotation of crankshaft main bearings 20.

With particular reference to Figure 2, a polishing shoe assembly according to the prior art is illustrated. Polishing shoe assembly 10 includes two halves, upper shoe 32 and lower shoe 34 (shown partially in phantom lines). These halves are each connected to a support structure which may include hydraulic or pneumatic biasing cylinders acting on the shoe halves (as shown in phantom lines in Figure 2) or may be supported by a scissors type linkage device. This polishing shoe assembly employs a semicircular surface 24 having a plurality of spaced dovetail-shaped grooves 26. Within dovetail grooves 26 are installed cooperatively shaped urethane inserts 28. These inserts, due to the material from which they are made, are comparatively flexible and compressible, having a Durometer hardness of 90 or less. Each of the shoe portions include means for engaging coated abrasive tape 30 which is brought into compressive contact with the surface of pin bearing 18. At the conclusion of the microfinishing operation of one pin bearing 18, upper and lower shoes 32 and 34 are caused to separate and are repositioned and clamped onto another pin bearing 18 or a main bearing 20. Alternatively, a plurality of polishing shoe assemblies may be provided such that the entire workpiece may be machined in one operation. Simultaneous with shoe disengagement and re-engagement is an indexing of tape 30 such that a predetermined length of new abrasive material is brought into shoe assembly 10. This indexing results in the abrasive surface being constantly renewed.

Figure 3 illustrates a cross-sectional view taken through Figure 2 and shows contact between insert 28 and pin bearing 18. Insert 28 is caused to traverse relating to the surface of pin bearing 18 as indicated by arrow A. Insert 28, being made of a flexible material, is caused to conform to the existing surface profile of pin bearing 18. Therefore, if imperfections such as waviness, taper, convexness or concavity of the bearing surface exist, coated abrasive tape 30 will be caused to conform to the incorrect shape. As a result, this prior art microfinishing method does not correct geometry variations of the parts being microfinished.

Figure 4 shows polishing shoe assembly 60 according to a first embodiment of this invention. Polishing shoe assembly 60 includes upper shoe 62 and lower shoe 64. Polishing shoe assembly 60 varies principally from shoe assembly 10 shown by Figures 2 and 3 in that urethane inserts 28 are replaced with stone inserts 36. These inserts are preferably made from honing stone material. Stones inserts 36 are characterized in that they are relatively non-deformable having a Durometer hardness greater than 90, yet are easily machined and provide a degree of frictional engagement with coated abrasive tape 30. Each of stone inserts 36 are mounted to a holder 38. Stone inserts 36 and holders 38 are preferably permitted to "float" slightly with respect to the upper and lower shoes, enabling them to rotate slightly as indicated by arrow B in Figure 5. Such relative rotation is provided according to this embodiment by mounting holders 38 using mounting pins 40. Like shoe assembly 10, coated abrasive tape 30 is supported by shoes 62 and 64 such that when they engage pin bearing surface 18, the tape is brought into contact with the surface being microfinished.

The principal advantages of the configuration of polishing shoe assembly 60 are best explained with reference to Figure 5. Stone insert 36 is provided which presents a surface having a predetermined curvature which is rigid and which exerts a compressive load on tape 30 against pin bearing 18. Since stone inserts 36 are rigid and relatively non-conformable, surface waviness, taper, convexity and concavity of the surface of pin bearing 18 are corrected since, in these instances, nonconforming portions of the surface of pin bearing 18 will be brought under greater contact pressures against coated abrasive tape 30, and therefore, more material will be removed in those areas until pin bearing 18 assumes the desired surface profile. Coated abrasive tape 30 is preferably of a polymeric plastic film variety which is in itself relatively incompressible. Abrasive coated paper products are generally unsuitable for use in connection with this invention since they are relatively compressible as compared to polymeric plastic tape materials. Additionally, the grit size of abrasive coated papers is generally not as uniform as that of abrasive coated polymeric plastic tape materials. As with the prior art devices, insert 36 and shoe assembly 60 is caused to oscillate relative to pin bearing 18 as the bearing is rotated relative to the shoe assembly, as indicated by arrow A in Figure 5. Such lateral movement is achieved by moving the workpiece relative to polishing shoe assembly 62, or by moving the polishing shoe assembly relative to the workpiece, or a combination of both. When relative lateral movement is initiated, frictional engagement between stone insert 36 and coated abrasive tape 30 is necessary in order to urge the tape to move to a new lateral location. For this reason, hard materials having a very smooth surface such as machined metals are generally unsuitable for insert 36, unless they are sufficiently roughened to frictionally engage the back of coated tape 30. Materials which have been found suitable for insert 36 are conventional honing stone materials. These materials exhibit the desired hardness and frictional characteristics and have been found to produce excellent results.

Other types of coated abrasive tape material 30 could be employed in connection with this invention. For example, a metal backed tape which is coated with abrasive material could also be used.

Figures 6 and 7 illustrate a second embodiment according to this invention. For this embodiment, portions of insert 136 are partially relieved such that they do not cause high contact pressure between coated abrasive tape 30 and pin bearing 18. Figure 6 shows a pair of opposed relief portions 142 which are defined by arcuate borders 144. The surface of pin bearing 18 moves with respect to insert 136 in the direction indicated by arrow C. This second embodiment causes greater abrasive material removal to occur at the separated ends of the surface of pin bearing 18. This second embodiment therefore tends to cause the pin bearing surface to assume a slightly barrel shaped configuration, such that its diameters at each end are slightly less than the diameter at the center. Such "barrelling" is sometimes desirable to achieve optimal bearing surfaces.

A third embodiment according to this invention is shown with reference to Figures 8 and 9. This embodiment also produces a slightly barrel shaped journal bearing surface but achieves this result in a different manner than that according to Figures 6 and 7. A modified cylindrical contour in insert 236 is produced so that the radius of the curved insert surface at points near the ends of the journal bearing is less than at the center of the journal bearing. As shown by Figure 8, relative movement of pin bearing 18 with respect to insert 236 occurs along the direction indicated by arrow C. As illustrated by Figure 9, portions of the surface of insert 236 near the lateral edges are designated by reference character 254 and have a radius of curvature somewhat less than that of central shoe segment 256 (these differences in radius are exaggerated in Figure 9 for illustration purposes). This embodiment, therefore, provides another means for generating a non-cylindrical surface and a workpiece being machined. According to this embodiment, such machining results from machining the desired surface contour directly into stone insert 236 and this contour will be impressed and machined in the corresponding workpiece.

A fourth embodiment of this invention is illustrated by Figure 10, which enables the side wall portion 68 of pin bearing 18 to be finished and further permits any burrs existing between filet radius 46 and the bearing surface to be removed. In accordance with this embodiment, flexible inserts 348 and 350 are provided with inserts 36. These flexible inserts exert a compressive force against coated abrasive tape 30 when the inserts are brought to their extreme lateral positions. Although the employment of a flexible material for inserts 348 and 350 results in the same shortcomings associated with conventional processes, it is generally not necessary to highly control the profile shape of these surfaces. Since it is necessary for tape 30 to flex to a considerable extent when brought into contact with side wall portion 68, it is sometimes necessary to provide edge cuts within the coated tape, according to principles known to the prior art. Use of inserts 348 and 350 further permits the elimination of burrs or sharp edges which may exist at the edges 51 of the bearing surface of journal 18 when the fillet radius are cut deep into the workpiece (as shown by Figure 10). By mounting inserts 348 and 350 such that they exert a slight compressive load on the surface of bearing 18, tape 30 is caused to remove such burrs when the insert forces the tape into the fillet.

Figure 11 illustrates a fifth embodiment according to this invention. This embodiment employs inserts 36 and upper and lower shoes 62 and 64 as described in connection with Figure 4. This embodiment differs from the previously described embodiments in that coated abrasive tape 430 is used which has a multiplicity of perforations 452 along its length. Perforations 452 enable lubricants or cutting fluids to come in contact with the surfaces being machined. Flow of lubricant or cutting fluids to the workpiece is conducted through passage 70 within upper and lower shoes 62 and 64.

A sixth embodiment according to this invention is described with reference to Figure 12. As shown by that Figure, lower shoe 564 is mounted within cradle 566 by a mounting pin 540. These mounting pins permit rotation of lower shoe assembly 564 with respect to cradle 566. A similar mounting arrangement would also be provided for upper shoe assembly 562 (not shown). This arrangement provides the desirable "floating" characteristic as described with reference to Figure 4 wherein individual mounting pins 40 are provided for each of the inserts 36. The construction illustrated by Figure 12 has the primary advantage of being simpler to construct. In operation, this embodiment performs as described in connection with the earlier described embodiments.

A seventh embodiment according to this invention is shown by Figures 13 and 14. This embodiment provides another means of finishing the side wall portions 68 of a bearing 18 or 20. In accordance with this embodiment, upper shoe 62 and/or lower shoe 64 include elastomeric insert 672 which is employed to polish the side wall portions 68. As shown by Figure 13, upper shoe 62 and lower shoe 64 are constructed identical to that described with reference to Figure 4 except that one or more of stone inserts 36 is replaced by elastomeric insert 672. Elastomeric insert 672 is particularly shown in detail by Figure 14. As shown by that Figure, insert 672 is made from an elastomeric substance such as a urethane compound and includes radiused edge surfaces 674 and 676. Insert 672 has a lateral width which exceeds that of stone inserts 36 such that as polishing shoe assembly 60 is stroked laterally, radiused side surfaces 674 and 676 cause coated abrasive tape 30 to contact side wall portions 68, thereby microfinishing that area. Preferably, elastomeric insert 672 is resiliently biased within the associated shoe portion, enabling it to move radially and laterally with respect to the associated bearing surface. As shown by Figure 14, lateral compliance of elastomeric insert 672 is provided by employing drill rod 678 which flexes, enabling the insert to move laterally with respect to upper shoe 62. The maximum extent of lateral compliance is limited by contact between elastomeric insert 672 and insert holder 682. Radial compliance for insert 672 is provided by employing helical coil spring 680 which exerts a downward compressive force upon coated abrasive tape 30. The maximum extent of radial displacement is controlled by the position of head 684 on drill rod 678. This embodiment provides another means of gaining the advantages of a rigid insert in accordance with this invention and further finishing the side wall and radius portions of the bearing surface being microfinished.

While the above description constitutes the -preferred embodiments of the present invention, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope and fair meaning of the accompanying claims.

CLAIMS

1. A machine for microfinishing a surface of a workpiece, said machine using coated abrasive tape as the machining agent, comprising:

means for rotating said workpiece,

a shoe assembly having means for attaching said tape and having at least one rigid insert which presses said tape into contact with said workpiece surface, and

an arm which supports said shoe assembly such that relative movement between said workpiece surface and said tape occurs as said workpiece is rotated relative to said tape.

2. The machine for microfinishing a surface of a workpiece according to Claim 1, wherein said rigid insert is mounted to said shoe assembly by a mounting pin such that slight relative rotation of said rigid insert with respect to said shoe assembly is permitted.

3. The machine for microfinishing a surface of a workpiece according to Claim 1, wherein said rigid insert is mounted to said shoe assembly and said shoe assembly is mounted for rotation about a mounting pin such that slight relative rotation of said shoe assembly with respect to said workpiece is permitted.

4. The machine for microfinishing a surface of a workpiece according to Claim 1, wherein said rigid insert is composed of honing stone material.

5. The machine for microfinishing a surface of a workpiece according to Claim 1, wherein said rigid insert has a hardness exceeding 90 Durometer.

6. The machine for microfinishing a surface of a workpiece according to Claim 1, wherein said machine is useful for microfinishing outside surfaces of workpieces and wherein said insert forms a predetermined surface shape which relates to the desired workpiece surface shape, said insert surface pressing said tape into contact with said workpiece surface whereby said workpiece surface is caused to conform to the shape of said insert surface.

7. The machine according to Claim 6 wherein said shoe assembly includes upper and lower shoe portions, each of said portions having at least one rigid insert.

8. The machine according to Claim 6 wherein all portions of said insert surface extend over the same circumferential distance.

9. The machine according to Claim 6 wherein said insert surface extends over greater circumferential distances at its lateral ends such that more material is removed from selected areas of said workpiece surface.

10. The machine according to Claim 6 wherein said insert surface is shaped having cylindrical segments of varying radius, thereby forming a desired profile shape in said workpiece.

11. The machine according to Claim 6 wherein said workpiece surfaces terminate laterally with radially outwardly projecting surfaces thereby forming a fillet radius therebetween, said rigid insert further including at least one elastomeric insert mounted adjacent said rigid insert which presses said tape into contact with said fillet radius.

12. The machine according to Claim 6 further comprising, one or more second inserts made from an elastic material having a lateral width greater said rigid insert, said second insert applying a compressive force against radially outwardly projecting surfaces of said workpiece and thereby finishing said surface.

13. The machine according to Claim 12 further comprising, resilient mounting means for said second insert which becomes deflected as said shoe assembly is moved to its extreme lateral positions.

14. An insert for a microfinishing machine of the type wherein said insert presses coated abrasive tape against a workpiece surface as said tape moves relative to said workpiece surface, comprising: said insert having a predetermined surface shape related to the desired workpiece surface shape, said insert made from a rigid material which does not conform to the surface shape of said workpiece surface, whereby said insert causes said desired workpiece shape to be machined on said workpiece.

15. An insert for a microfinishing machine according to Claim 14, wherein said insert is made from stone.

16. The insert for a microfinishing machine according to Claim 15, wherein said insert has a hardness exceeding 90 Durometer.

17. An insert for a microfinishing machine of the type according to Claim 14 wherein said insert presses coated abrasive tape against a substantially cylindrical workpiece surface, said insert forming a surface which defines a portion of a cylinder.

18. An insert for a microfinishing machine according to Claim 17, wherein all portions of said insert surface extend along the same circumferential distance.

19. The insert according to Claim 14 wherein portions of said insert surface extend along greater circumferential distances than other portions of said insert surface.

20. The insert according to Claim 17 wherein said insert surface is shaped having cylindrical surfaces of varying radius.

21. A method of microfinishing a workpiece surface which comprises the steps of

rotating said workpiece and,

causing an insert to press a coated abrasive tape against said workpiece surface, said insert having a predetermined surface shape related to the desired workpiece surface, said insert being rigid whereby said insert does not conform to the surface shape of said workpiece surface, whereby a desired workpiece surface is generated in said workpiece surface.

22. The method according to Claim 21 wherein said insert has a hardness exceeding 90 Durometer.

23. The method according to Claim 21 further comprising the step of causing a second elastomeric insert to press said coated abrasive tape against said workpiece surface and against the radially outwardly projecting surfaces of said workpiece.

24. The method according to Claim 21 further comprising the step of moving said insert laterally as said workpiece is rotated.

25. The machine for microfinishing a surface of a workpiece according to Claim 1 wherein said rigid insert is composed of a metal having a roughened surface which presses against said workpiece surface.

26. An insert for a microfinishing machine according to Claim 14 wherein said insert is composed of a metal having a roughened surface which presses against said workpiece surface.

Fig-1

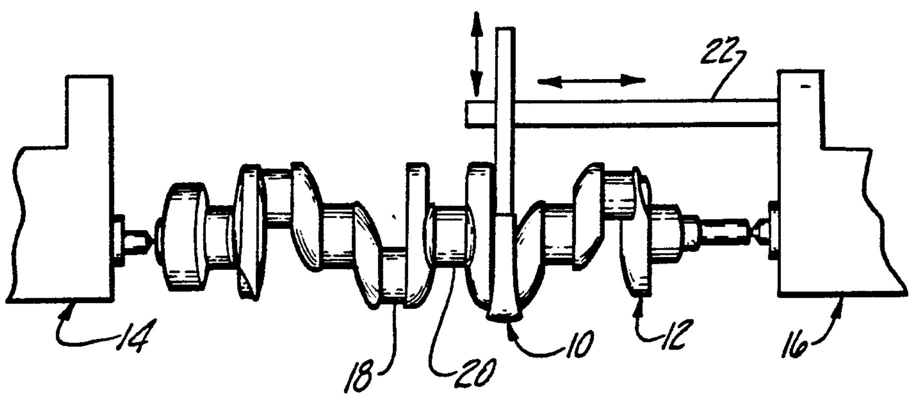
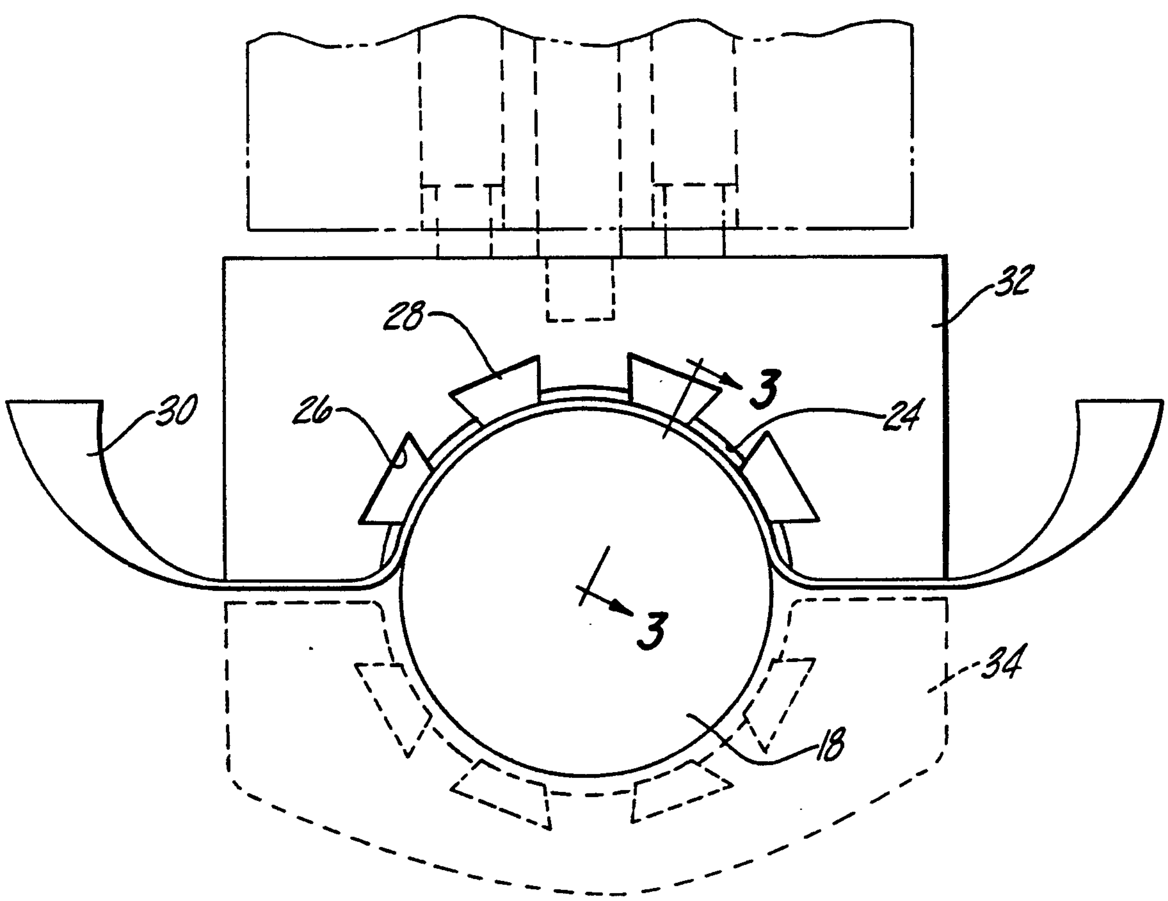


Fig-2



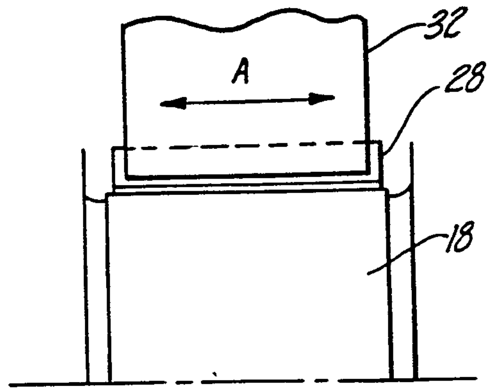


Fig-3

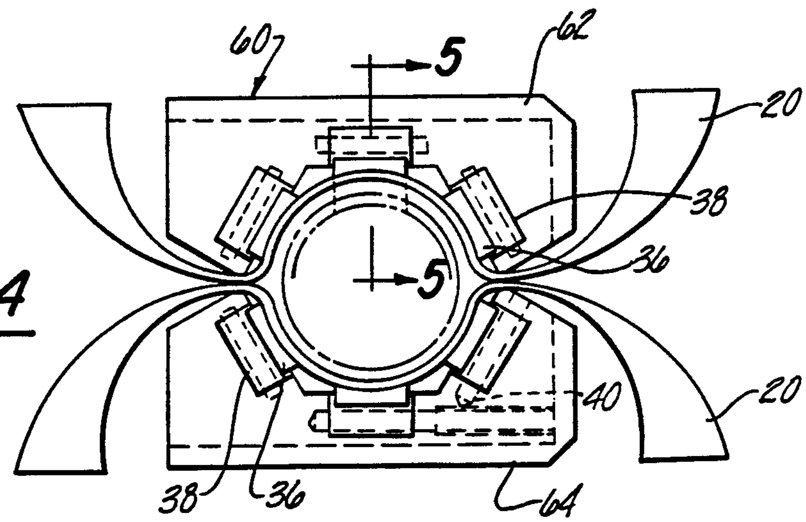


Fig-4

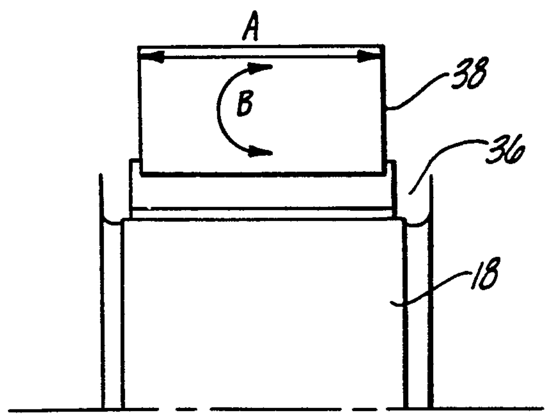


Fig-5

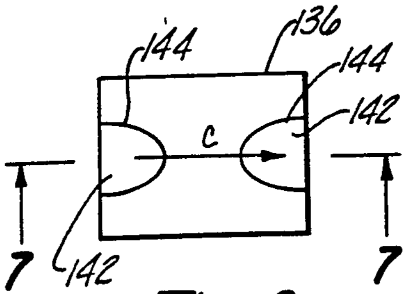


Fig-6

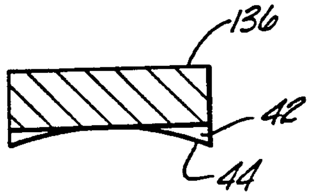


Fig-7

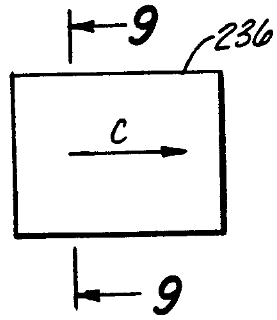


Fig-8

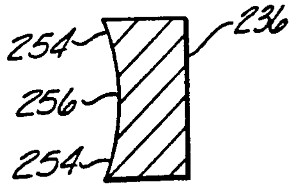


Fig-9

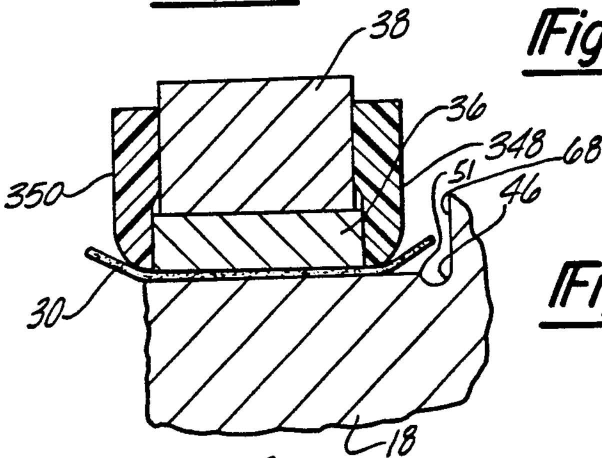


Fig-10

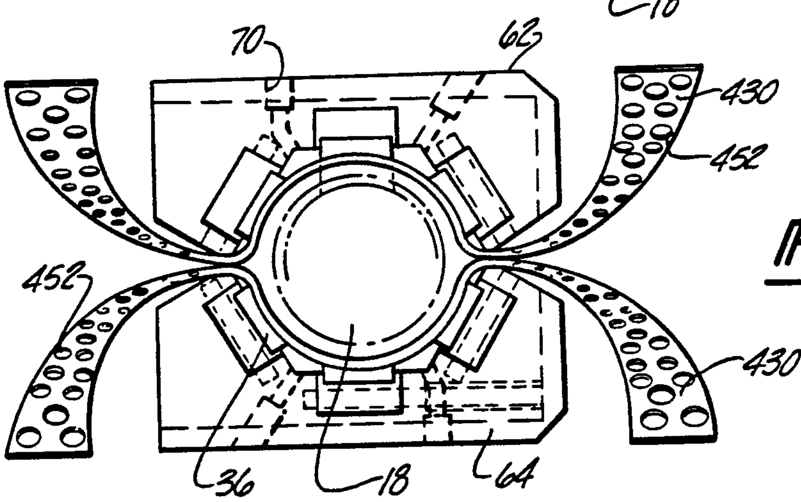


Fig-11

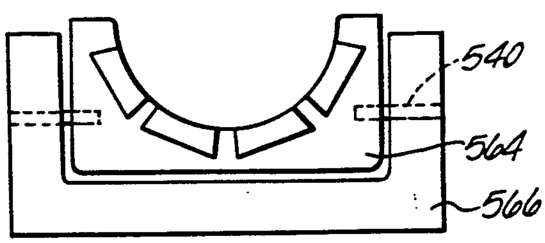


Fig-12

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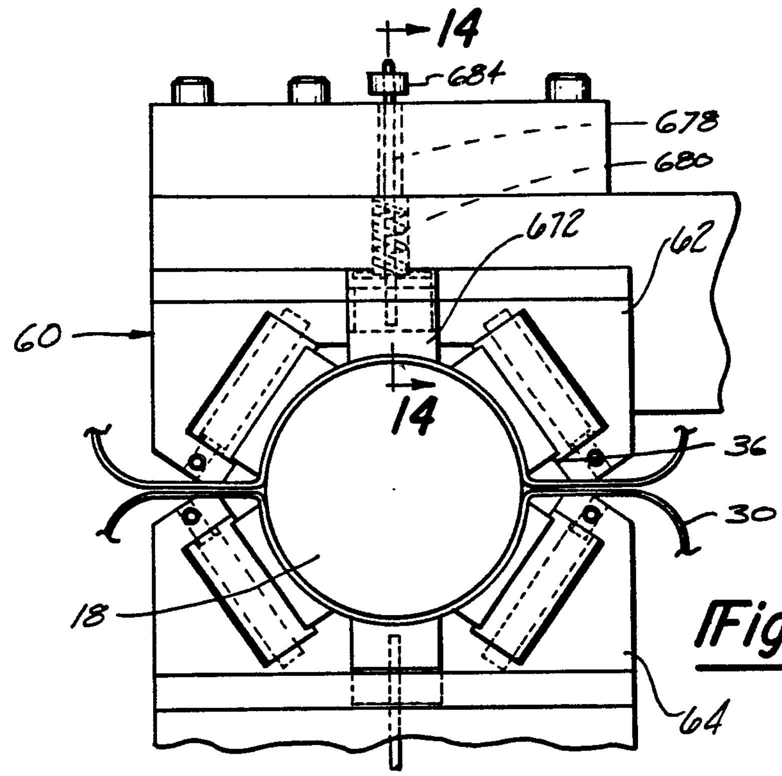
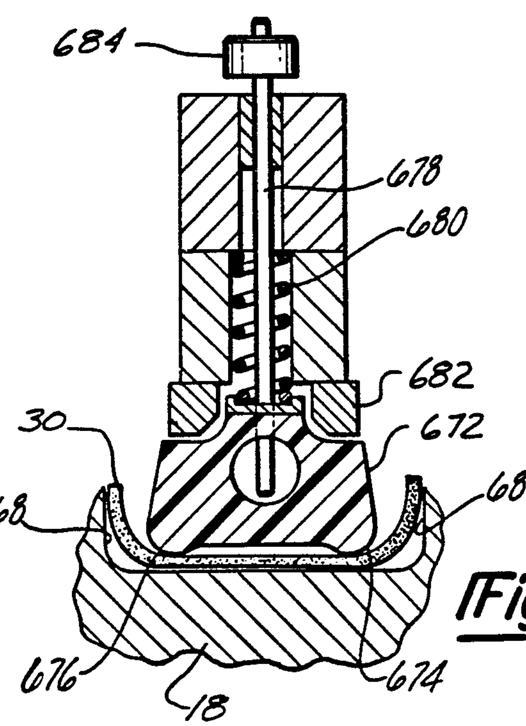


IFig-13



IFig-14